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EFFECTS OF COMPETITION AND MODE OF FIRE ON PHYSIOLOGICAL RESPONSES, PSYCHOLOGICAL STRESS REACTIONS, AND SHOOTING PERFORMANCE

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U.S. ARMY HUMAN ENGINEERING LABORATORY

Aberdeen Proving Ground, Maryland

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This research supported the Advanced Combat Rifle field test and the Human Engineering Laboratory (HEL) stress program by evaluating competition as a methodology for producing a known level of stress in soldiers. The subjects in this field experiment were volunteer infantrymen from the 82nd Airborne Division and the 101st Airborne Division (Air Assault). During the 2 competition weeks, 10 soldiers from each division participated; during the control week, 20 soldiers form the 82nd Airborne Division served as subjects. The subjects fired M855 ball ammunition loaded into 30-round magazines from M16A2 rifles equipped with Crane Naval Weapons Support Center No. 1 muzzle devices. Each subject fired two different target scenarios during the record-fire days, one scenario in semiautomatic mode and one in burst mode. Each scenario consisted of 36 target presentation events. Events involved presenting one, two, or three targets for 1.5, 3, or 5 seconds at 50, 100, 200, or 300 meters. The stress created by competition was assessed by comparing the psychological and physiological responses of the soldiers firing competitively with the responses of soldiers firing during noncompetitive, control conditions, and with the responses obtained from subjects in other stress protocols. Psychological reactions were measured by a battery of commercially available instruments and by an instrument developed by HEL for its stress program. Physiological reactions were determined by measuring several stress-reactive hormones in multiple blood samples and by monitoring heart rate during the interval surrounding record fire.

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In this experiment, the authors (1) demonstrated that competition can be used to reliably produce a moderate level of stress, as measured by HEL stress metrics; (2) showed that aim error was greater in burst mode than in semiautomatic mode but generated aim errors lower than previously estimated; (3) confirmed that a relatively high burst dispersion coupled with a relatively low aim error did not improve burst mode; and (4) helped define the limits of performance for a relatively high impulse serial burst system such as the M16A2.

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The soldiers who participated in this field experiment were housed in barracks provided by B Company, 141st Ordnance Battalion, 61st Ordnance Brigade, U.S. Army Ordnance Center and School. They used the nearby 141st Ordnance Battalion dining facility for their morning and evening meals. The cooperation and assistance provided by these units is gratefully acknowledged.

The Services and Support Division of the Human Engineering Laboratory provided valuable assistance to this experiment, including fabrication, maintenance, and range operation. The Close Combat-Light and Heavy Division provided essential range operation programs and personnel who assisted in operating the range control computer. This support was vital to the success of this field experiment.

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EXECUTIVE SUMMARY

INTRODUCTION

The present research supported the Advanced Combat Rifle (ACR) field test by providing estimates of aiming error and hit probability for single round and burst modes of fire as a function of target exposure time, number of targets presented, and target range. This project also supported the ACR program by evaluating competition as a methodology for producing a known level of stress in soldiers while measuring their performance of combat-relevant tasks. The procedure for stressing soldiers employed the psychological stresses of competition, threats to self-esteem, peer pressure, team interdependency, and pursuit of awards and public recognition, while manipulating the task-related variables of target range, target number, and target exposure time.

In addition, the Human Engineering Laboratory (HEL) stress program was advanced by these data. The fundamental goals of this program include developing standard procedures for soldier and equipment performance testing, as well as obtaining extensive physiological and psychological response data in a number of studies investigating different kinds and intensities of stressful situations. The physiological and psychological data from the present field study helped to determine (a) whether the soldiers involved in competitive marksmanship exhibited typical stress responses, (b) the level and intensity of their stress experience, and (c) how the level of stress related to their marksmanship performance.

METHOD

The subjects in this field experiment were 60 volunteer infantrymen from the 82nd Airborne Division and the 101st Airborne Division (Air Assault). During the 2 competition weeks, 10 soldiers from each division participated in the experiment; during the control week, 20 soldiers from one division served as subjects.

The subjects fired M855 ball ammunition from M16A2 rifles which had been equipped with the Crane Naval Weapons Support Center (NWSC) No. 1 muzzle devices to control burst dispersion. These devices provide the best muzzle control of any devices tested which still permitted the required sustained rate of fire. The firing was conducted at HEL's M range. The stress created by competition was assessed by comparing the psychological and physiological responses of the soldiers firing competitively with the responses of soldiers firing during noncompetitive, control conditions, and with the responses obtained from subjects in other stress protocols. Psychological reactions were measured by a battery of commercially available instruments and by an instrument developed by HEL for its stress program. Physiological reactions were determined by measuring several stress-reactive hormones in multiple blood samples and by monitoring heart rate during the interval surrounding record fire.

The first and third weeks were competition weeks during which groups from each unit competed for a plaque and other recognition, while the second week was a control week during which no competition occurred. Tuesdays were occupied with surveys, zeroing of weapons, and familiarization firing. On Wednesdays, baseline blood samples and stress survey responses were obtained, and additional familiarization firing was conducted. On Thursdays, the record firing scenarios were presented to the subjects, and the record firing hormone samples and stress surveys were taken. Each subject fired two different randomly selected target scenarios on the record-fire days, one in semiautomatic mode and one in three-round burst mode. Each scenario consisted of 36 target presentation events. Each event presented one, two, or three targets for 1.5, 3, or 5 seconds at 50, 100, 200, or 300 meters. The subjects were told to try to hit as many targets as possible, and they were instructed not to worry about ammunition expenditure. The scenarios were stopped when necessary to allow magazine changes.

RESULTS AND DISCUSSION

The Army Materiel Systems Analysis Agency (AMSAA) has shown that approximately an 8-mil extreme spread for a three-round burst is optimal for an aiming error function which has been accepted by the analytical community as representative of combat stress. The aiming error function represents the aiming performance of the worst third of various small arms field experiments. Aiming error is a negative exponential function of range whose values vary from a high of a 12-mil standard deviation at 25 meters to a low of 2 mils at 600 meters. Note that the burst dispersion of the M16A2 is 22 mils, and the M16A2 equipped with NWSC No. 1 muzzle device achieves 16 mils. AMSAA's predictions showed that little improvement could be expected from a system with a 16-mil extreme spread except at close range. The only significant improvement in targets hit found in this experiment was at 50 meters, confirming this prediction.

ACR concepts are expected to be an improvement in comparison to the M16A2, based on two assumptions: (1) During the stress of combat, aiming errors will be large; and (2) firing multiple projectiles per trigger pull, either serially or simultaneously, will increase hit probability beyond that of firing a single round per trigger pull. The degree of improvement depends on the aiming error associated with the trigger pull, the number of rounds fired, and the size of their dispersion. The projected improvements of ACR concepts in comparison to the M16A2 further assumed that the aiming error, although large, would be the same for semiautomatic and burst fire. This experiment failed to achieve aiming errors as large as those described by the AMSAA worst third aiming error function. Further, the results showed that aiming error associated with burst fire was larger than that associated with semiautomatic fire.

To determine whether a significant level of stress was generated in the study and to determine the relative degree of stress generated, batteries of psychological and physiological measures, developed by reference to the stress literature, were employed. Evaluations were made by reference to the literature and by reference to results obtained in the stress studies using these measures as a part of the HEL stress program.

Comparison of the Competition and Control Groups indicated that the Competition Group showed consistently and significantly greater stress-related response changes in the endocrine measures as a function of firing during competition than did the Control Group as a function of the same firing during noncompetitive conditions. The endocrine data obtained for the Competition and Control Groups 15 minutes after firing for record were also compared with the endocrine data obtained at the same relative time point in stress protocols from basic research contractual efforts at Northwestern University. This comparison revealed that the Competition Group had a response profile very similar to that obtained for medical students taking an important written examination, which is a moderately stressful situation. The Control Group, on the other hand, had a profile more characteristic of other, relatively non-stressful control conditions.

The psychological data revealed response profiles for the Competition and Control Groups that reinforce the conclusions reached, based on the physiological data. Consistent with the interpretation that the Competition Group was under more stress than the Control Group, the Competition Group subjects expressed significantly greater state anxiety than control subjects both 15 minutes before and after firing on record-fire day, and they rated the firing as significantly more stressful than the control subjects did. Additionally, the Competition Group subjects expressed greater hostility and lower positive affect 15 minutes after firing. Both findings appear to reflect greater dissatisfaction with personal performance during competitive conditions.

The profiles of psychological data for the Competition and Control Groups compared with profiles for the Northwestern stress studies yielded results that were very much like those for the physiological data. The anxiety expressed by the Competition Group appears most comparable to that of the group of medical students taking a written exam. This finding parallels the comparisons for the endocrinological data and supports the interpretation that a moderate level of stress was experienced by the Competition Group.

Although this study was initiated with two primary and separate objectives, namely, creating a method for generating stress in test situations and evaluating modes of fire to be used in the ACR field test, analyses of correlational relationships between the data obtained for these two purposes yielded interesting information. The marksmanship performance measures used were the numbers of targets hit in the semiautomatic and burst modes.

Two demographic measures were related to performance, measured as targets hit. The longer the soldiers reported being in the Army, the better they performed in the burst mode; the greater variety of weapons for which they were currently qualified, the better their performance was in the semiautomatic mode.

With regard to the hormone data, different relationships with performance existed depending on whether the subjects performed during competitive conditions. For the Control Group, lower prolactin levels early in the morning of baseline day and relatively higher prolactin levels early in the morning of record-fire day were significantly correlated with better performance. For the Competition Group, lower testosterone levels on baseline day were significantly correlated with better performance in the burst mode, and a relatively lower testosterone level early in the morning of record-fire day was significantly correlated with better performance in the semiautomatic mode. Significant positive correlations were obtained for both groups between burst mode performance and change in testosterone level from baseline to record-fire day at the +15-minute time point. The correlations appear to be attributable to better performance by those showing a smaller stress reaction.

Two personality measures were also related to targets hit. Lower scores on both the Multiple Affect Adjective Checklist-Revised (MAACL-R) Depression and Hostility trait subscales were significantly correlated with better performance on this measure. However, none of the state stress-perception measures, which were given on baseline day or before firing on record-fire day, were correlated with performance.

Some of the psychological measures obtained after firing on record-fire day did correlate with performance. Those Control Group subjects who reported using more avoidance behaviors in coping with the stress did not perform as well as those who did not tend to use that coping mechanism.

Two post-firing MAACL-R state measures correlated significantly with performance. Competition Group subjects who performed well reported higher Sensation Seeking scores that reflect higher levels of excitation. Control Group subjects who performed worse in the burst mode reported higher Hostility scores that reflect higher levels of frustration.

This study demonstrated that competition can be used to generate stress in subjects. The level of stress generated does not appear to have been sufficiently intense to have adversely affected the performance of the Competition Group relative to controls. Future applications of a method for generating stress in systems evaluations will require a level of stress comparable to combat-induced stress levels. Research about methods of generating a higher level of stress will have to continue. The results of this study suggest that competition might serve as one component of a methodology that might include either multiple stressors or acute and chronic stressors.

CONCLUSIONS

This experiment (1) demonstrated that competition can be used to reliably produce a moderate level of stress, although that level was insufficient to degrade group level performance of the shooting task; (2) showed that aim error was greater in burst mode than in semiautomatic mode; (3) found that a relatively high burst dispersion coupled with a relatively low aim error did not improve burst mode. In addition, this experiment (4) failed to achieve aiming errors as large as those described by the AMSAA worst third aiming error function.

THE EFFECTS OF COMPETITION AND MODE OF FIRE ON PHYSIOLOGICAL RESPONSES, PSYCHOLOGICAL STRESS REACTIONS, AND SHOOTING PERFORMANCE

CHAPTER 1

INTRODUCTION

(J. M. King, J. P. Torre, Jr., G. A. Hudgens)

A major function of human factors research organizations is to measure the performance of soldiers as operators of equipment, to be concerned with those aspects of equipment design that either contribute to or detract from operator-maintainer performance during operational conditions, and to suggest ways to best combine these two factors. This thrust is at the heart of the human factors domain of the Manpower and Personnel Integration (MANPRINT) Program (MANPRINT Manager's Course, 1986). Many data in this area are presently collected during relatively benign but controlled laboratory conditions, in uncontrolled field studies, in nonexperimental demonstrations, and in a variety of developmental and operational tests. Many of these studies are primarily tests of the equipment that do not manipulate the variables, which would require the operators to perform during stressful conditions. Nearly all of the soldier equipment that is developed is intended to be operated by soldiers during the stress of combat.

STRESS

It would seem to be desirable to evaluate soldier-operator performance during the most extreme conditions when the system is likely to operate. This would be helpful in evaluating the performance of the system and in determining its effectiveness in operations research studies. However, it is neither ethically nor legally feasible to expose soldiers to real danger in order to stress them in an experiment. Other alternatives must be sought.

In an attempt to mimic some of the effects of combat stress, it is first necessary to define the elements of combat stress and to determine their nature. At that point, one must decide which of these elements are amenable to manipulation during controlled conditions. Field experiments are then needed to validate the variables chosen. At this point, a set of standard procedures for testing soldier-equipment performance during stressful conditions could be developed. This is only one of the goals toward which this experiment was directed.

One of the most stressful aspects of combat is the ever-present threat to life and limb. Outside of war, however, data cannot be collected about performance that is influenced by this particular stressor. Efforts to induce individuals not involved in combat to believe that they are in imminent danger to life and limb have been attempted (Berkun, Bialek, Kern, & Yagi, 1962; Berkun, 1964). These studies were successful in meeting this goal, and the subjects' performance was disrupted. Torre and Kramer (1966) showed that fire from a BB machine gun, directed at the shooter, could stress that soldier, even when he was heavily encumbered with protective gear. The procedures employed to stress subjects in this case depended on the threat of discomfort for their effectiveness. Some aspects of the combat situation, other than the threat of discomfort or injury, appear to lend themselves to direct experimental manipulation. These include (among others) peer and leader pressure to perform well for the good of the unit as a whole, individual and collective readiness to meet the demands of the situation, the amount of information available about tho situation, the amount of physical or mental effort required, task difficulty, and the degree of fatigue.

The present work is an attempt to extend past research to include soldiers using individual equipment to accomplish military tasks when exposed to a real but non-injurious psychological stressor--competition. Soldiers' performance would also reflect on the unit, and would have consequences for unit esprit de corps. Their self-esteem and sense of self worth would thus seem to be at risk in such a situation, potentially adding to the perceived stress levels. A body of scientific and anecdotal evidence suggests that competition can be much more stressful than a subjective analysis of the situation would lead one to predict. Anticipation of, performance in, and denial of expected participation in a competition altered an index of adrenal activity, heart rate, and respiratory rate in direct relationship to the psychological demands of the competitive situation and to the relevant past experiences of the subjects (Ulrich, 1957). In more recent studies, a soldier-of-the-month competition has been found to elevate heart rate and to raise blood levels of adrenocorticotropic hormone (ACTH), endorphin, prolactin, and cortisol (Meyerhoff, Oleshansky, & Mougey, 1988). In addition, a competitive peg board game elevated anxiety, heart rate, and blood pressure in study test participants (Karteroliotis & Gill, 1987). Thus, competition can introduce stress, variously measured, into a wide variety of situations.

Stress responses can be measured in several ways. Among the ways available are the following: monitoring hormone levels in blood (Rose, 1980); using surveys (Kerle & Bialek, 1958); gauging psychophysiological reactions (Lader, 1975); and obtaining data about actual task performance (Berkun et al., 1962). Each of these approaches has unique limitations. No single hormonal measure will adequately assess stress (Mason, 1974; Rose, 1980). Surveys depend on the honesty of the respondent, the accuracy of their recall, and their willingness to share personal information (Bradburn, Rips, & Shevell, 1987). Individual psychophysiological measures can also contradict each other (Mason, 1971). In the case of task performance, the quality of the action is related to the perceived stress level by a complex function, the effect of which is generally to produce lower levels of performance at very low and at very high stress levels and to produce higher levels of performance at moderate stress levels (Hockey, 1986). Overlaying all these concerns is the problem of individual differences in response to stress.

Individual differences in perceptions of stress are also important here (Mason, 1975), as are individual variations in personality traits and coping strategy (Rose, 1980). Widely accepted research has demonstrated the advantage of using multiple indices of stress to obtain an accurate assessment of the stress level inherent in a situation. Mason (1974) and Fibiger and Singer (1984) have shown that different stresses yield distinct physiological response profiles, while Swenson and Vogel (1983) have found that the intensity of the stressor can alter the response profile by changing the duration of the response.

As noted above, research and theory indicate that patterns or profiles of physiological and psychological stress responses vary according to the kind and intensity of stress experienced (Mason, 1974). The picture emerging from this research area is that it should be possible, by using multiple stress indices, to develop a stress metric procedure. This has been a major objective of HEL's stress research program (Hudgens, Torre, Chatterton, Wansack, Fatkin, & DeLeon-Jones, 1986). HEL presently has a preliminary version of such a metric procedure available for determining, in a relative sense, how stressed subjects are when experiencing other stressors, such as those imposed on the soldiers who participated in this field experiment. It is the authors' intent to apply this preliminary metric to studies of soldier-weapon system performance during stress conditions, as is the case in the present research, to determine whether and to what extent the human element in the system is stressed by the experimental conditions.

Through contracts with Northwestern University and Westside Veterans' Administration Hospital, a basic research program was initiated to obtain profiles of physiological and psychological responses from people experiencing differing kinds and intensities of stress. Examination (medical students during a critical examination) and surgical (spouses of patients undergoing surgery) stress were chosen for study in this program because they appeared to share several elements with combat stress, for example, the threat to one's ego and career if one does not perform to expectations and the threat to life or limb--in this case, of a loved one.

Significant progress has been made in this effort. In the surgical stress protocols, data are available from spouses of patients undergoing both major abdominal and minor outpatient surgery. During the examination protocol, data collection is complete for the medical students taking a highly critical written examination (e.g., Hudgens, Chatterton, Torre, Slager, Fatkin, Keith, Rebar, DeLeon-Jones, & King, 1989). Extensive data from unstressed Control Groups are also available for use in our analyses.

In summary, sufficient data have been collected about response profiles at the control, low stress (surgical), and moderate stress (surgical and examination) levels for these kinds of stress, so that preliminary evaluations can be made of other stress situations that fall within the range of the moderate stresses produced to date. Continuing work in this research program is focused upon completion of the initial metric including high stress response profiles. Thus, we have a usable preliminary version of a stress metric to support the analysis and evaluation of the stress levels produced in the present experiment.

SOLDIER-RIFLE PERFORMANCE

To support the ACR field test design in terms of specifying target behaviors, shooter procedures, and test analyses, the Joint Services Small Arms Program (JSSAP) committee requested that HEL (a) determine if the aim errors accepted by the analytical community as indicative of combat stress could be generated by task-induced stressors coupled with the psychological stress of competition; and (b) compare the performance of the M16A2 equipped with the NWSC No. 1 device firing in both semiautomatic and burst modes of fire with respect to hit probability and aim error.

The findings of Torre (1985); Feldman, Reed, Hazell, Tiller, Michelsen, Walton, Pettijohn, and Yudowitch (1959); Feldman, Reed, Hazell, Love, Tiller, Pettijohn, Yudowitch, and Michelsen (1961); Klein and Tierney (1978) indicate that short target exposures, random presentations, and multiple targets are representative of task-induced stressors in combat. To generate high aim errors in this study, a day defense scenario was constructed in which man silhouette targets were randomly presented at unknown ranges from 50 to 300 meters for short time periods singly and in multiples of two and three. In addition, the stress of competition was added by including many of the variables found in the literature that would promote maximum stress, one of which was threat to self-esteem, which was generated by having two elite groups of soldiers compete in rifle marksmanship a task expected of infantrymen which reflects upon their unit and themselves.

This study provides data that may influence the ACR program by providing estimates of aiming error and hit probability for single round and burst modes of fire, and by providing a methodology for producing a known level of experimental stress in soldiers.

APPROACH

This experiment (i.e., the Salvo Stress Study) employed a multivariate approach to the study of stress. Data were collected for several hormonal responses, heart rate was studied in selected subjects, surveys were used to estimate perceived stress and to assess aspects of personality, and the soldiers' performance with the rifle in both single and burst mode was measured. The authors believe this is the best approach to attack the complex issues involved in studying reactions to and performance during conditions of stress.

In designing and conducting this study, great care was taken to ensure the safety of the subjects. The blood-sampling procedures were developed in consultation with medical and nursing professionals and were approved by the Medical Research and Development Command Human Use Office (Tauson, 1986a). This approval was subsequently reaffirmed (King, 1987). The protocol had been approved as minimal risk investigation by the HEL Human Use and Experimental Design Panel (Tauson, 1986b). The NWSC No. 1 muzzle device used to control burst dispersion had received a U.S. Army Test and Evaluation Command (TECOM) safety certification before use in the study (Dixon, 1988). All firing was conducted in accordance with HEL (1987), which covers the M range facility at which the study was conducted.

OBJECTIVES

This study was designed to (a) assist in developing a procedure to stress soldiers while measuring their performance of combat-relevant tasks, and adding to the data base in this area; and (b) provide data to assess the feasibility of meeting stated requirements for the ACR program using a serial burst system with the recoil impulse of an M16A2.

GENERAL METHOD

Subjects

The subjects in this field experiment were 60 volunteer infantrymen, 40 from the 82nd Airborne Division and 20 from the 101st Airborne Division (Air Assault). Units willing to support this field experiment by permitting HEL to recruit volunteers were identified through the Test Scheduling and Review Committee (Department of the Army, 1985) process in coordination with Forces Command (FORSCOM) Headquarters. During the 2 competition weeks, 10 soldiers from each division participated in the experiment; during the control week, 20 soldiers from the 82nd Airborne Division served as subjects. All the subjects had been briefed about the experiment at their home bases and had signed volunteer agreement affidavits before traveling to Aberdeen Proving Ground (APG). The subjects were again asked to sign this agreement (see Appendix A) upon their arrival at APG.

Apparatus

The subjects fired M855 ball ammunition loaded into 30-round magazines from M16A2 rifles which had been equipped with NWSC No. 1 muzzle devices to control dispersion in burst mode. The safety certification for this muzzle device is contained in Appendix B. The firing was conducted at the HEL automated and instrumented small arms facility at M range. This facility is further described in Appendix C. Blood samples for hormonal analysis were collected using standard indwelling catheters, syringes, and tubes, and were collected in accordance with standard medical conditions by clinical laboratory technicians under the supervision of a registered nurse. Sampling was conducted in a climate-controlled trailer immediately behind the firing point. Blood samples were analyzed by a contractor. These procedures are described in Chapter 3 of this report and in Appendix D. A battery of psychological surveys was also assembled to measure personality variables and to assess reactions to the situation. These are described in Chapter 4 and in Appendix E of this report. The heart rate data-collection apparatus is described in Chapter 5.

Procedures

The experiment was conducted during the weeks of 7, 14, and 21 March 1988 at APG, MD. The weather conditions for these weeks are summarized in Appendix F. The first and third weeks were competition weeks during which the soldiers from each unit competed for a plaque awarded to the high scoring unit and for other recognition, while the second week was a control week during which no formal competition occurred. During competition weeks, the soldiers were briefed by the Commander, HEL, before record fire began, and they were advised that high ranking visitors could be expected at the range. During competition firing, soldiers were encouraged to remain in the stands provided to observe their peers' performance, and most of them did so. A large scoreboard was placed near the stands, and each soldier's score was announced over the public address system and posted on the scoreboard along with a running total for his team. A video camera and recorder were placed behind the firing point to record shooting performance during competition. During the noncompetition week, soldiers were briefed by the field experiment director, and the soldiers were permitted to rest in the tent behind the control trailer except when they were actually firing. The video camera, recorder, and scoreboard were removed from the range for this week, and scores were not publicly announced.

The daily and weekly experimental schedules are given in Appendix G. During each week, Monday was reserved for traveling from home base, for inbriefing, and inprocessing. Tuesday was occupied with personality surveys, zeroing of weapons, and familiarization firing. On Wednesday, four baseline blood samples and baseline stress survey responses were obtained, and additional familiarization firing was conducted. On Thursday, the record firing scenarios were presented to the subjects, and the six record firing blood samples and the record fire stress surveys were taken. Each subject fired two different target scenarios on the record-fire days, one in semiautomatic mode and one in three-round burst mode. Each scenario consisted of 36 target presentation events. The blood samples and surveys were timed to occur at specified intervals before and after record firing and at corresponding times on the baseline days. On Wednesdays and Thursdays, subjects were not given lunch until after their last blood samples had been taken. The subjects were advised to avoid drinking alcohol while at APG and to avoid all caffeine-containing beverages on blood-sampling days. A two-way radio, which was in contact with Kirk U.S. Army Health Clinic, was kept in the control trailer to be used to summon aid in case of an injury.

Statistical analyses of the data were conducted using the System for Statistics (SYSTAT) version 4.0 (Wilkinson, 1987), except as noted in a particular chapter. The alpha level for the analyses in this report was set at 0.05.

CHAPTER 2

SHOOTING PERFORMANCE DURING COMPETITION STRESS

(S. Wansack, J. P. Torre, Jr., J. M. King, J. Mazurczak, J. S. Breitenbach)

INTRODUCTION

The weapon user community has long expressed a need for a new or enhanced rifle for the combat soldier. The Advanced Combat Rifle (ACR) program has been developed to accommodate this need. The purpose of the ACR program is to develop and assess rifle concepts that will increase hit probability beyond that of the M16A2. The increase in hit probability rests on two assumptions. First, during the stress of combat, aiming errors will be large and second, firing multiple projectiles per trigger pull, either serially or simultaneously, will compensate for this large aiming error by increasing the probability of hit beyond firing a single projectile. The degree of improvement depends on the aiming error associated with the trigger pull, the number of rounds fired, and the size of their dispersion. The projected improvements of ACR concepts in comparison to the M16A2 further assume that the aiming error, although large, will be the same for semiautomatic and burst fire. The larger the aiming error, the greater the improvement. This is true because as aiming error increases, the opportunity for the additional projectiles to contribute to hit probability increases. Conversely, for small aiming errors, improvements in hit probability for burst systems are diminished. At present, the analytical community accepts an aiming error function derived from the performance of the worst third of many field experiments, offered by AMSAA, as that which may be experienced during combat stress.

Theoretically based analyses (Fallin, 1969; Weaver, 1989) have led to a consensus in the small arms community that approximately an 8-mil mean extreme spread for a three-round burst is optimal for a serially fired system (Torre & Querido, 1990; Weaver, 1989).

The only reliable serially fired burst weapon capable of simulating ACR concepts is the M16A2 equipped with a muzzle brake. Currently among the more effective devices available for controlling the burst dispersion of the M16A2 is the Navy Weapons Systems Center (NWSC) No. 1 muzzle device chosen for use in this study. It does not induce reliability problems during the required rates of sustained fire (Spadie, 1986). However, its 16-mil mean extreme spread three-round burst only approaches the 8-mil dispersion considered optimal for a serial burst system.

Analyses of battlefield marksmanship (Torre, 1985; Feldman, Reed, Hazell, Tiller, Michelsen, Walton, Pettijohn, & Yudowitch, 1959; Feldman, Reed, Hazell, Love, Tiller, Pettijohn, Yudowitch, & Michelsen, 1961; Klein & Tierney, 1978) suggest that several task-induced stressors would generate the large aiming errors expect in combat. The most apparent are the expectation of short target exposures, unknown target locations, multiple targets, and random combinations of these.

To support the ACR field test design in terms of specifying target behaviors, shooter procedures, and test analyses, the JSSAP committee requested that HEL (a) determine if the aim errors of the magnitude predicted by the AMSAA worst third function could be generated by task-induced stressors coupled with the psychological stress of competition; and (b) compare the performance of the M16A2 equipped with the NWSC No. 1 device firing in both semiautomatic and burst modes of fire with respect to hit probability and aim error. This field experiment accomplished both of these tasks.

Therefore, the Salvo Stress (SS) Study was conducted partly to determine if high aiming errors would be generated by adding the stress of competition to the task-induced stressors such as short target exposure time, random presentation of multiple targets at differing ranges, and second, to determine if aiming error changes when multiple projectiles are fired per trigger pull in comparison to aiming error that results from firing a single projectile. The intent was to use the information obtained from this experiment to assist in designing the ACR field test to compare concepts and to assist in the assessment methodology.

Concurrent with this JSSAP effort, HEL, in conjunction with the Army Development and Employment Agency (ADEA) (Department of the Army, 1985), has been developing a methodology to stress soldiers in experimental settings while measuring their performance of combat-relevant tasks. The stressing procedures being considered employed the psychological stresses of competition, threats to self-esteem, peer pressure, team interdependency, and pursuit of awards and public recognition, while manipulating the task-related variables of target range, target number, and target exposure time.

A day defense scenario provided the combat-relevant tasks upon which to make performance measures in semiautomatic and burst modes of fire, as well as the vehicle to assess the NWSC No. 1 device and the effects of competition stress on performance.

METHODS

Subjects

The subjects (see Chapter 1 for details) were shooters recruited from elite infantry units. In addition to basic rifle marksmanship training, all subjects had expert record fire qualifications scores. Sixty percent of the soldiers recruited had also received M21 sniper training. To the extent that these soldiers were atypical, their expertise only served to increase their stress by raising the pressure on them to perform well, while minimally impacting the first two objectives.

Apparatus

The M16A2s used in this study (see Chapter 1 for details) were equipped with NWSC No. 1 muzzle devices. All firing was conducted in accordance with HEL (1987), which covers the M range facility at which the study was conducted. Since the NWSC No. 1 is not part of the current M16A2 configuration, a safety release was obtained from TECOM at APG (Dixon, 1988; see Appendix B). The characteristics of the M16A2 flash hider and the NWSC No. 1 device are given in Table 1. Standard E silhouette layered targets measuring 40 inches high by 20 inches wide and M855 ammunition were used throughout the field experiment.

Procedures

Each soldier was issued an M16A2 equipped with an NWSC No. 1 device for use throughout the test week. No replacement weapons were required. Subjects wore the battle dress uniform (BDU) and the personal armor system ground troops (PASGT) helmet during all firing. Each soldier went through the firing sequence described below. Firing was done from the foxhole-supported position.

Each soldier zeroed the weapon firing at the 25-meter scaled zeroing target for the M16A2. The procedure followed is outlined in the current training guidelines (Marine Corps, 1983). The rear sight elevation knob was set one click right of the 300-meter mark (8/3 setting). Aim point was at target center. The soldier fired three self-paced rounds at the target. If the shot group was sufficiently tight, any required adjustments were made. This procedure was repeated until all three rounds were covered by the zeroing circle superimposed on the target. After the 25-meter zero was completed, the rear sight elevation knob was rotated left one click (3/8 setting). The weapon was then zeroed for 300 meters.

Each soldier was given four 30-round magazines of M855 ammunition for familiarization firing. The subjects were instructed as follows:

> Targets will be presented from 50 to 300 meters for a 5-second interval. The first magazine is fired in the semiautomatic mode at your individual pace. There is no limit to the number of trigger pulls taken at any target; rather it is left to your discretion to determine whether sufficient time remains for additional rounds to be fired. The next three magazines are fired in the burst mode (three rounds per trigger pull). The instructions outlined for the semiautomatic mode still apply, but you are encouraged to always attempt to fire three rounds per trigger pull as opposed to limiting the burst by controlling trigger pressure.

Table 1

Characteristics of the M16A2 Flash Hider and the NWSC No. 1 Device

M16A2 flash hider dimensions:	
	Length 1.75 inches
	Outside diameter 0.86 inch
	Weight 2.06 ounces
Performance values of M16A2 with standard flash hider	
	Recoil impulse 1.35 lb-sec
	Rate of fire 819 rounds per minute
	Mean extreme spread 22.4 mils
NWSC No. 1 device dimensions:	
	Length 1.80 inches
	Outside diameter 0.864 inch
	Weight 2.15 ounces
Performance values of M16A2 with NWSC No. 1 Device:	
	Recoil impulse 0.96 lb-sec
	Rate of fire 810 rounds per minute
	Mean extreme spread 15.8 mils

The NWSC No. 1 is a cylindrical device consisting of two sets of five slots arranged symmetrically about the vertical axis. The first set of slots is 0.125 inch wide and 0.3 inch long. The second set of slots is 0.19 inch wide and 0.675 inch long. The separation of the slots is 65°. The device has a 0.73-inch solid bottom.

During record fire, each soldier fired two scenarios, each with a different target presentation sequence. Each scenario consisted of 36 target presentation events. Events involved presenting one, two, or three targets for 1.5, 3, or 5 seconds at 50, 100, 200, or 300 meters. The target presentations were made in random order to eliminate any learning effects. Subject-sequence pairings were also randomly determined. See Appendix H for detailed descriptions of these scenarios.

All scenario presentations were stopped when necessary to allow magazine changes or correction of malfunctions. At the end of a scenario, alibis for the targets missed because of malfunctions were presented in the exact sequence missed and at the normal scenario pace. (Note. An alibi is defined as an opportunity to repeat a shot as a result of equipment malfunction.) Bursts of fewer than three rounds were not alibied. The subjects were instructed as follows:

> Two separate scenarios will be fired, one in the semiautomatic mode and the other in the burst mode. The order for mode of fire will be determined as you approach the lane. Firing should be done from the foxhole-supported position in the way that is most conducive to defeating the targets. There is no limit to the amount of ammunition that can be fired. You may fire as many rounds as you feel are needed to defeat the targets. Again, you are encouraged to take advantage of all three rounds using the burst mode.

The firing sequences and points of instruction about target engagement were the same for both the Competition and Control Groups. The points of instruction differed between groups about the explanation given to the soldiers for participation in the study before and after their arrival at the APG site. The Competition Groups were informed that a major issue was to determine which unit possessed the best rifle marksmanship program, and that this was not only of interest to HEL but to the Army in general. The groups were continually made aware that competition was to be keen and that they were expected to perform well. There were constant reminders, including video cameras to record their performance and newspaper articles discussing the competition, that the military community would be apprised of their performance. On the other hand, the Control Group was instructed that the reasons for their study participation were to provide firing data about a new muzzle device currently being investigated and to assess their reactions to participating in the experiment. Emphasis was placed on the need to accurately assess weapon performance, but no reference was made to high expectations regarding individual performance. Soldiers were explicitly instructed to refrain from discussing experimental procedures with subjects in subsequent groups until after the field experiment was completed.

The range was computer controlled, and all firing data were collected on line. Target presentations (see Appendix H for data concerning target range, target number, and target exposure time) were controlled using a scenario generation program written on a cassette and executed on a Hewlett-Packard 9100. This configuration allowed individual lane control. Since the targets were hit sensitive, an electrical short circuit caused by the projectile passing through the target registered as a hit and provided strike feedback to the soldier as well as hit and miss data to the computer. A firing pressure sensor adjacent to the muzzle of the weapon was used to trigger a shot counter and to time stamp the trigger pull in relation to the target up signal. Data were collected and stored on a Compaq computer. Upon completion of a scenario presentation, individual totals of target hits and shots fired were printed and saved as a disk file. For the stress groups, results were reported over a public address system, then posted on a scoreboard where running group totals were tallied. Any additional processing of data was done off line.

Data for each group were stored as an ASCII file and preprocessed using a Turbo Pascal® data reduction program written by Dr. Joel Kalb of the Auditory Performance Team, Behavioral Research Division, HEL. This program was based on work reported in Grubbs (1964). Statistical analyses were conducted using Statistical Analysis System (SAS, 1985).

RESULTS

The design employed groups (two competition versus one control), Mode of Fire (semiautomatic versus three-round burst), Range (50, 100, 200, and 300 meters), Target Exposure Time (1.5, 3.0, and 5.0 seconds), and number of Targets presented at a time (one, two, or three) as independent variables in a fixed effects analysis of variance (ANOVA), since groups were the experimental unit. The Groups x Mode x Range x Time x Target mean square interactions were used as the error term. Targets hit (Hits) were used as the dependent measure. Statistical analysis was done using SAS® Version 5.0 (1985). The data were subjected to log transformation before analysis. Post hoc analyses were conducted using Scheffé's Test with an alpha level of 0.05. Figures 1 through 3 show the hits for one target presented for 1.5, 3, and 5 seconds, respectively. Figures 4 through 6 show the hits for two targets presented for 1.5, 3, and 5 seconds, while Figures 7 through 9 show the hits for three targets presented for 1.5, 3, and 5 seconds.

Results of the ANOVA described above revealed that among the main effects, the groups variable had no overall effect on Hits ($F(2, 32) = 0.72$). Mode was significant ($F(1, 32) = 10.80$, $p<.0025$), reflecting more Hits in burst mode than in semiautomatic mode. The effect resulting from Range was significant ($F(3, 32) = 668.45$, $p<.0001$), indicating that Hits declined as range increased. Scheffé's test indicated that all four ranges differed from each other. Time of exposure had a major impact on Hits ($F(2, 32) = 1164.04$, $p<.0001$). More targets were hit at longer exposure times. All three exposure times differed from each other based on Scheffé's tests. The Target variable was also significant ($F(2, 32) = 97.63$, $p<.0001$). More Hits were obtained with three targets presented than one, but performance was lowest when two targets were exposed. Scheffé's test revealed that one, two, and three target exposures were different. The two target presentations required a large angular change in weapon orientation to engage either of the targets presented. Also, performance during the one and three target presentations was similar, because the center target, presented in both cases, was generally engaged first.

Among the two-way interactions, the Groups x Mode ($F(2, 32) = 0.34$), Groups x Target ($F(4, 32) = 2.14$), Mode x Range ($F(3, 32) = 0.63$), Mode x Time ($F(2, 32) = 2.47$), and Mode x Target ($F(2, 32) = 0.78$) interactions failed to achieve significance. The significant Groups x Range interaction ($F(6, 32) = 2.70$, $p<.031$) reflects the finding that the Control Group performed better than the Competition Groups at ranges less than 300 meters, while the Competition Groups obtained more Hits at 300 meters. The Groups x Time interaction ($F(4, 32) = 3.55$, $p<.017$) is a result of the first Competition Group's poor performance during 1.5-second exposure conditions. The Range x Time interaction ($F(6, 32) = 23.52$, $p<.0001$) indicates that the effects of decreased exposure times were exaggerated at longer ranges. The Range x Target interaction ($F(6, 32) = 13.63$, $p<.0001$) suggests that the detrimental

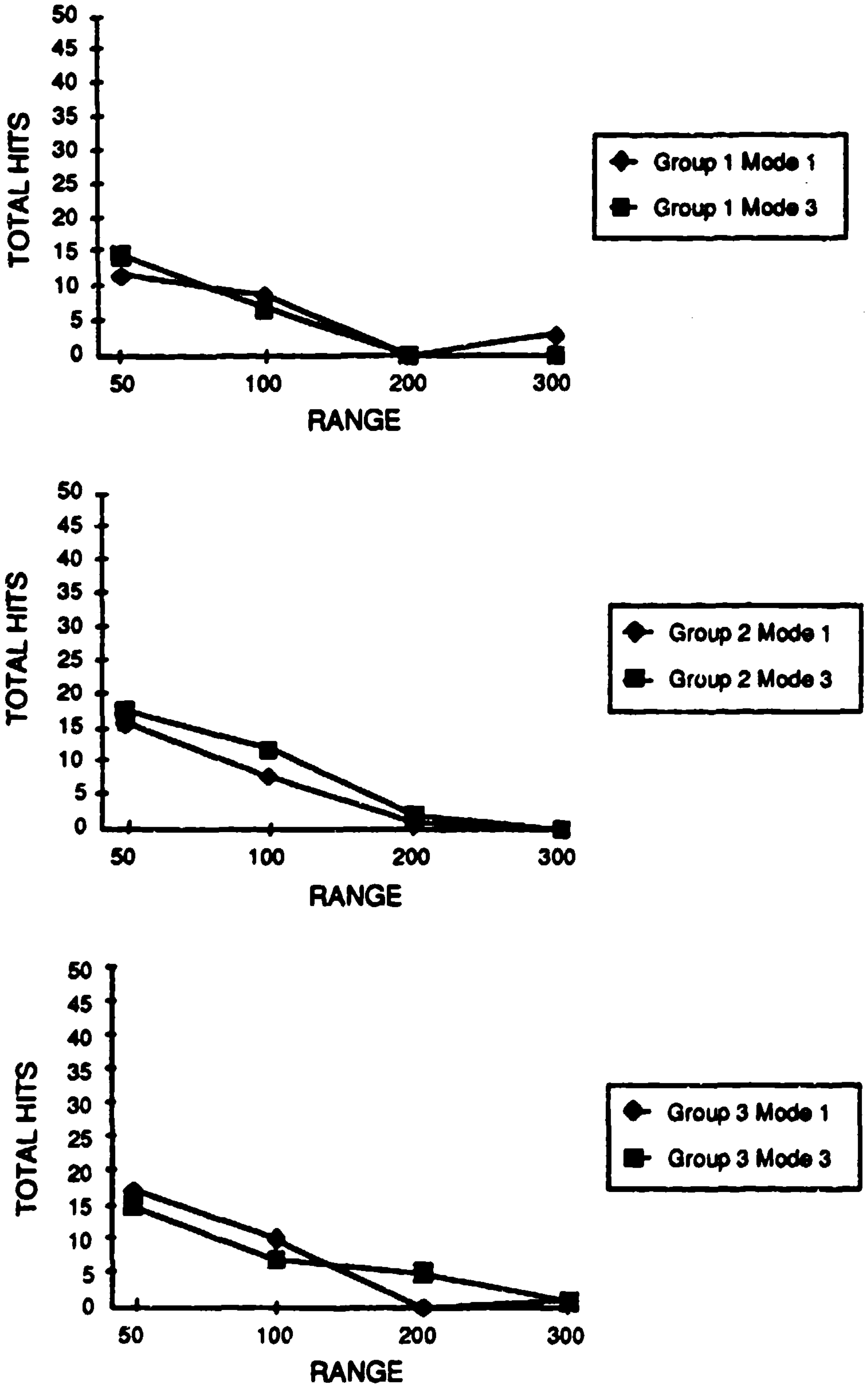


Figure 1. Hits for one target presented for 1.5 seconds as a function of mode of fire (Mode 1 = semiautomatic, Mode 3 = three-round burst) and range for Competition Group 1 (top), Control Group 2 (middle), and Competition Group 3 (bottom).

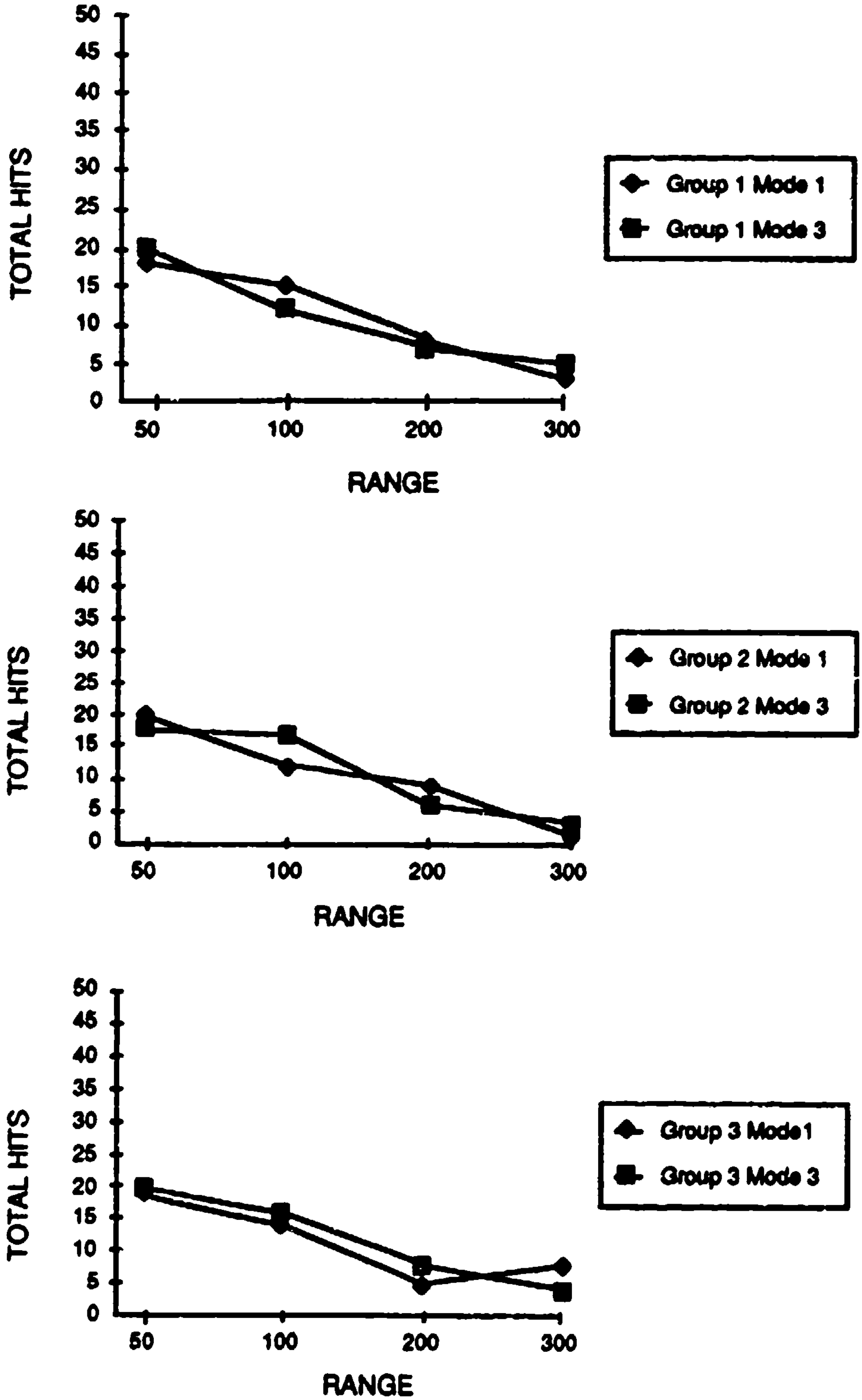


Figure 2. Hits for one target presented for 3 seconds as a function of mode of fire (Mode 1 = semiautomatic, Mode 3 = three-round burst) and range for Competition Group 1 (top), Control Group 2 (middle), and Competition Group 3 (bottom).

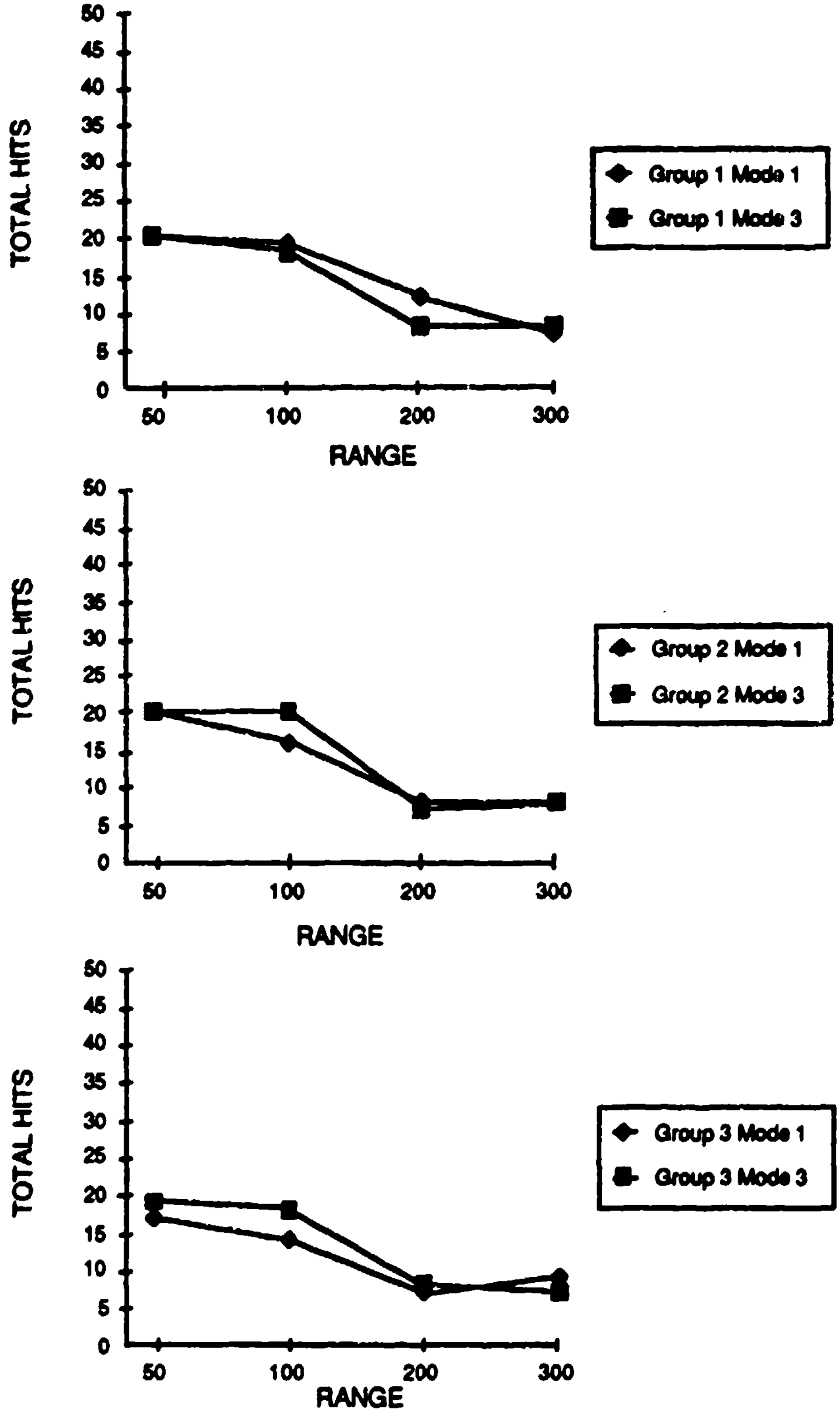


Figure 3. Hits for one target presented for 5 seconds as a function of mode of fire (Mode 1 = semiautomatic, Mode 3 = three-round burst) and range for Competition Group 1 (top), Control Group 2 (middle), and Competition Group 3 (bottom).

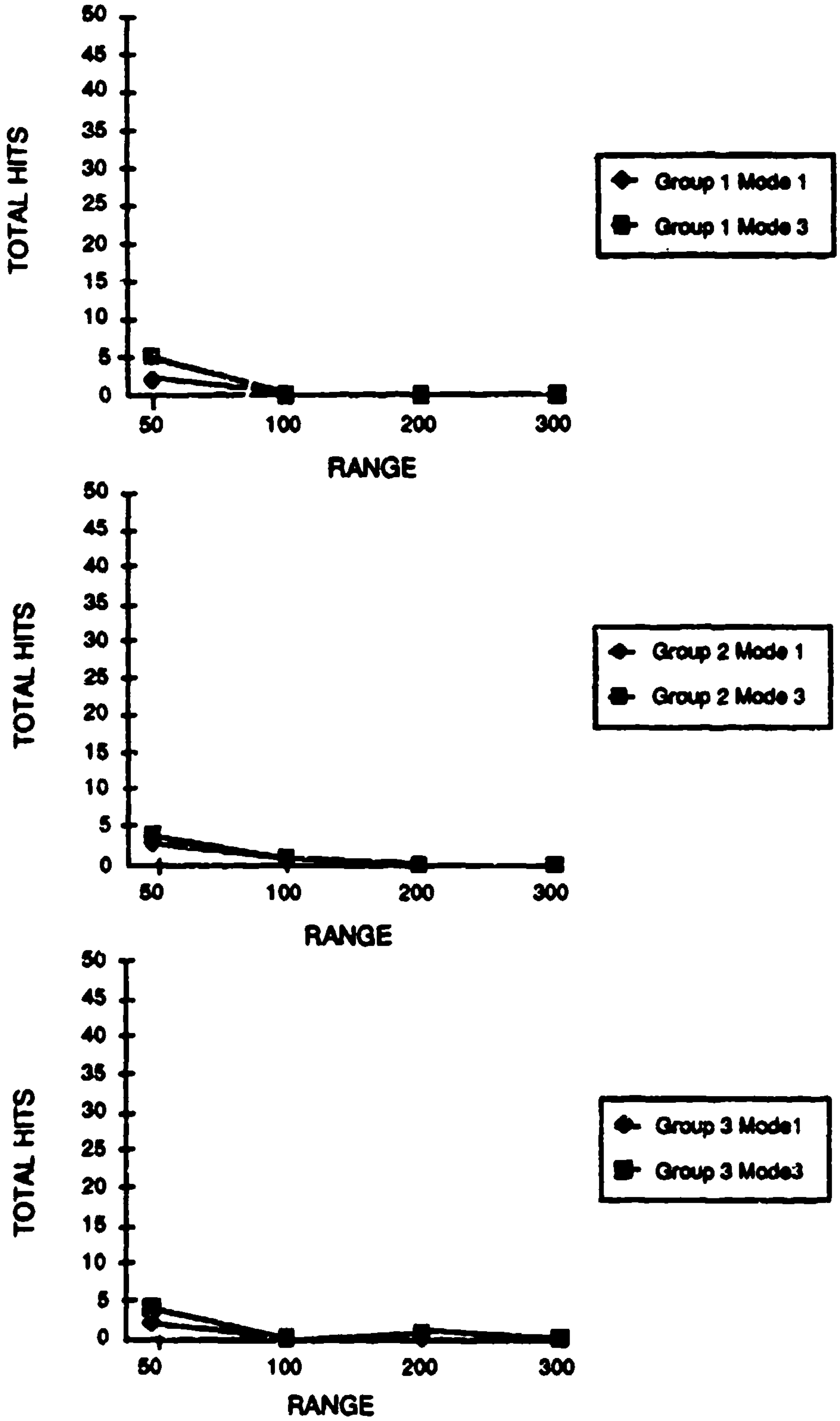


Figure 4. Hits for two targets presented for 1.5 seconds as a function of mode of fire (Mode 1 = semiautomatic, Mode 3 = three-round burst) and range for Competition Group 1 (top), Control Group 2 (middle), and Competition Group 3 (bottom).

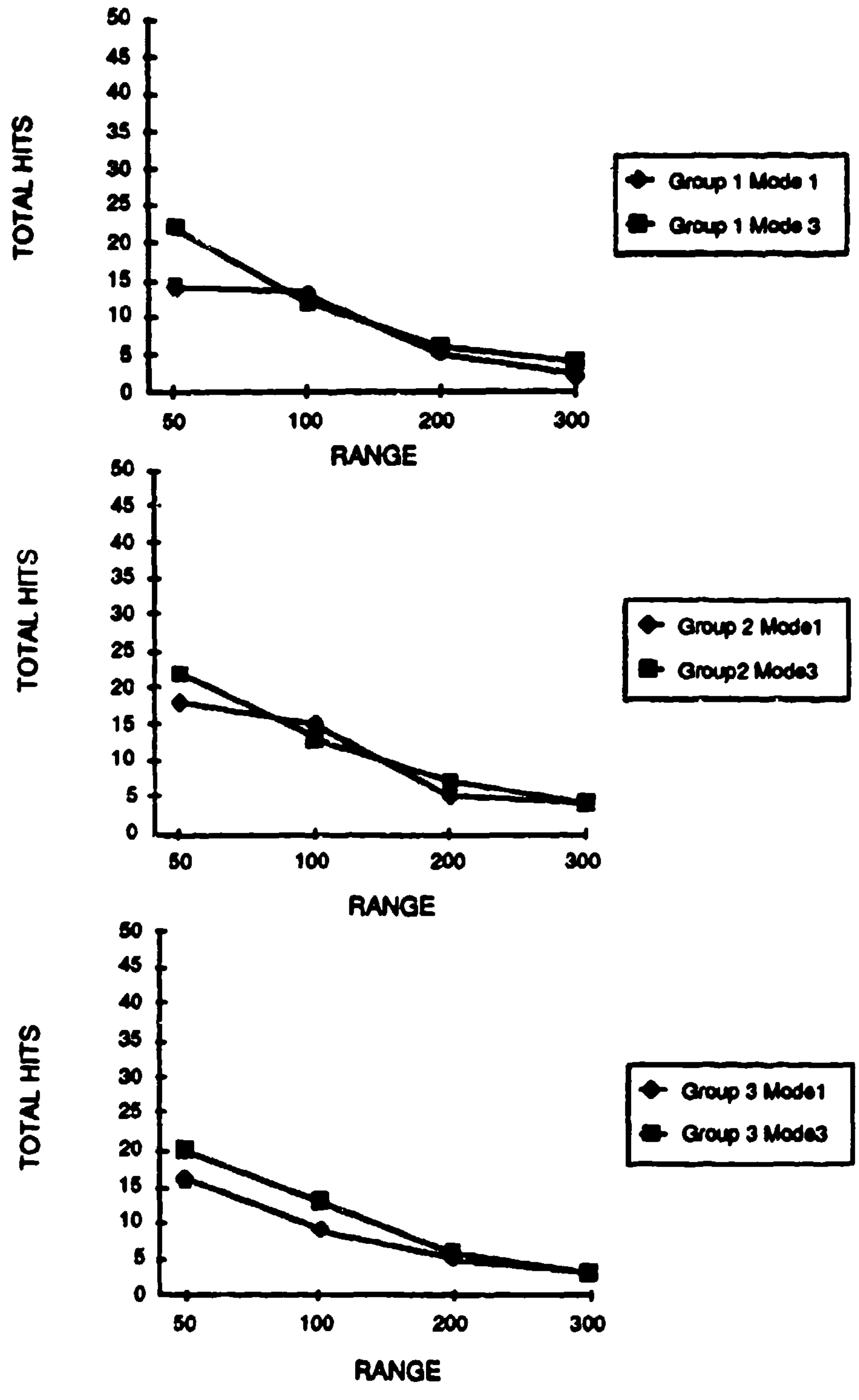


Figure 5. Hits for two targets presented for 3 seconds as a function of mode of fire (Mode 1 = semiautomatic, Mode 3 = three-round burst) and range for Competition Group 1 (top), Control Group 2 (middle), and Competition Group 3 (bottom).

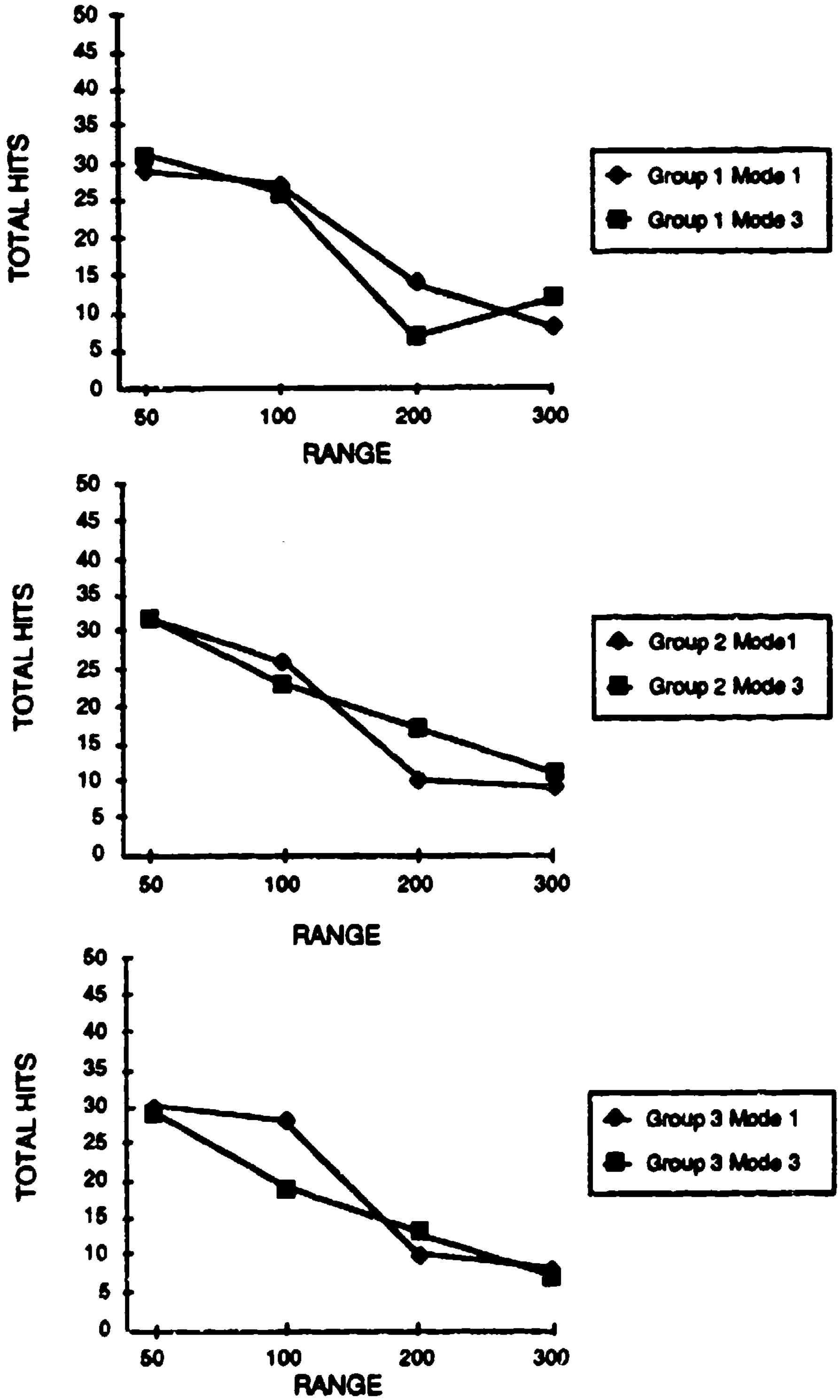


Figure 6. Hits for two targets presented for 5 seconds as a function of mode of fire (Mode 1 = semiautomatic, Mode 3 = three-round burst) and range for Competition Group 1 (top), Control Group 2 (middle), and Competition Group 3 (bottom).

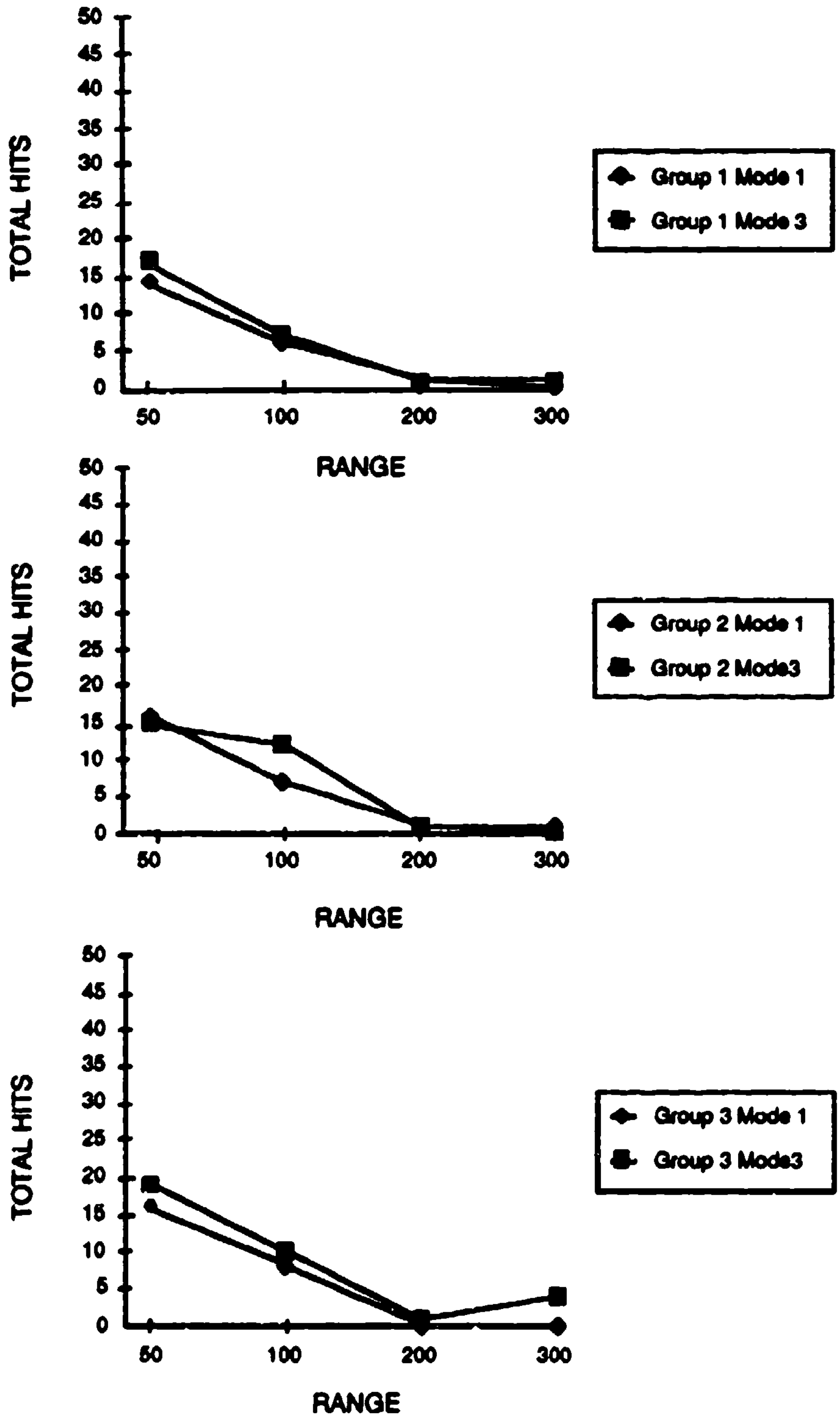


Figure 7. Hits for three targets presented for 1.5 seconds as a function of mode of fire (Mode 1 = semiautomatic, Mode 3 = three-round burst) and range for Competition Group 1 (top), Control Group 2 (middle), and Competition Group 3 (bottom).

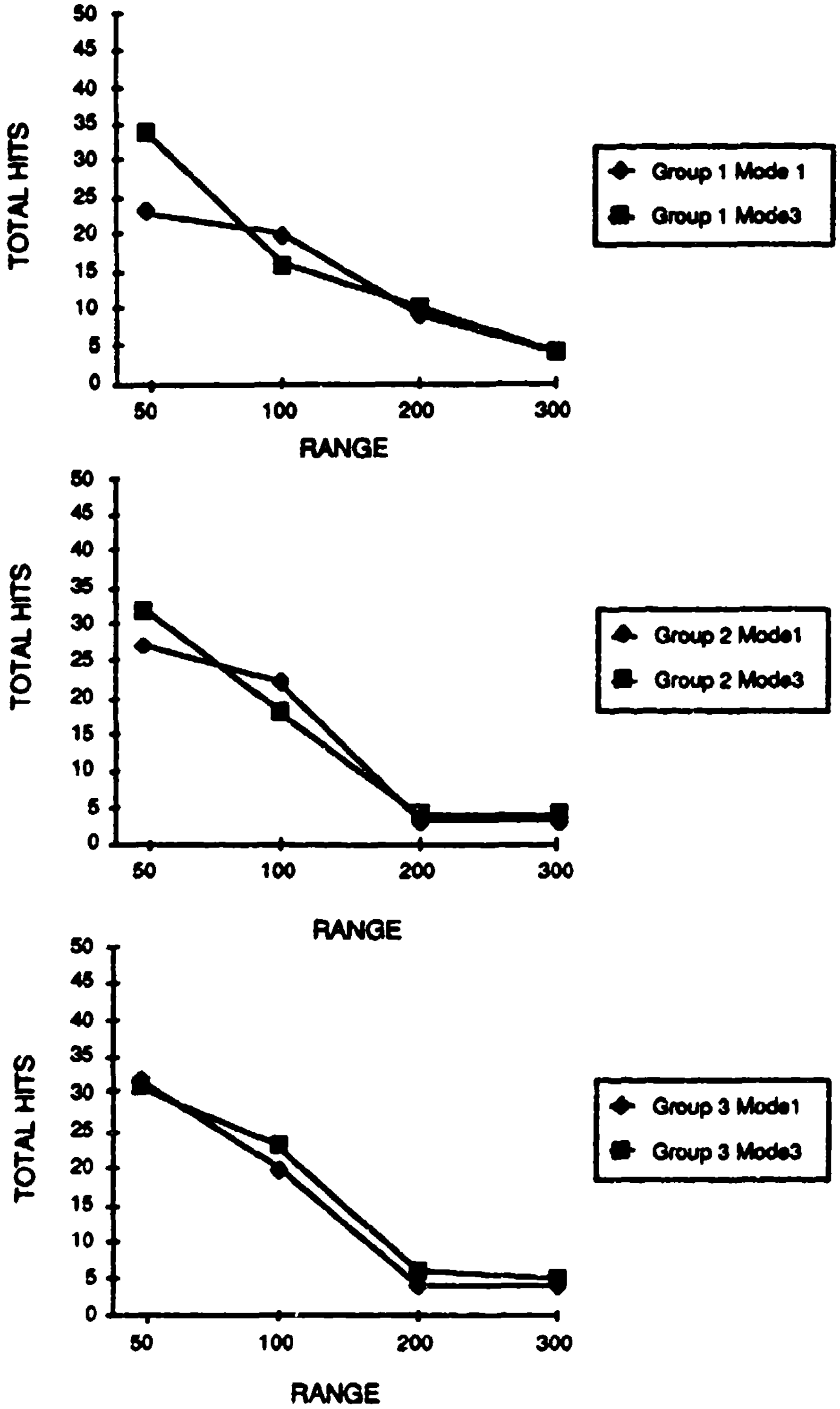


Figure 8. Hits for three targets presented for 3 seconds as a function of mode of fire (Mode 1 - semiautomatic, Mode 3 - three-round burst) and range for Competition Group 1 (top), Control Group 2 (middle), and Competition Group 3 (bottom).

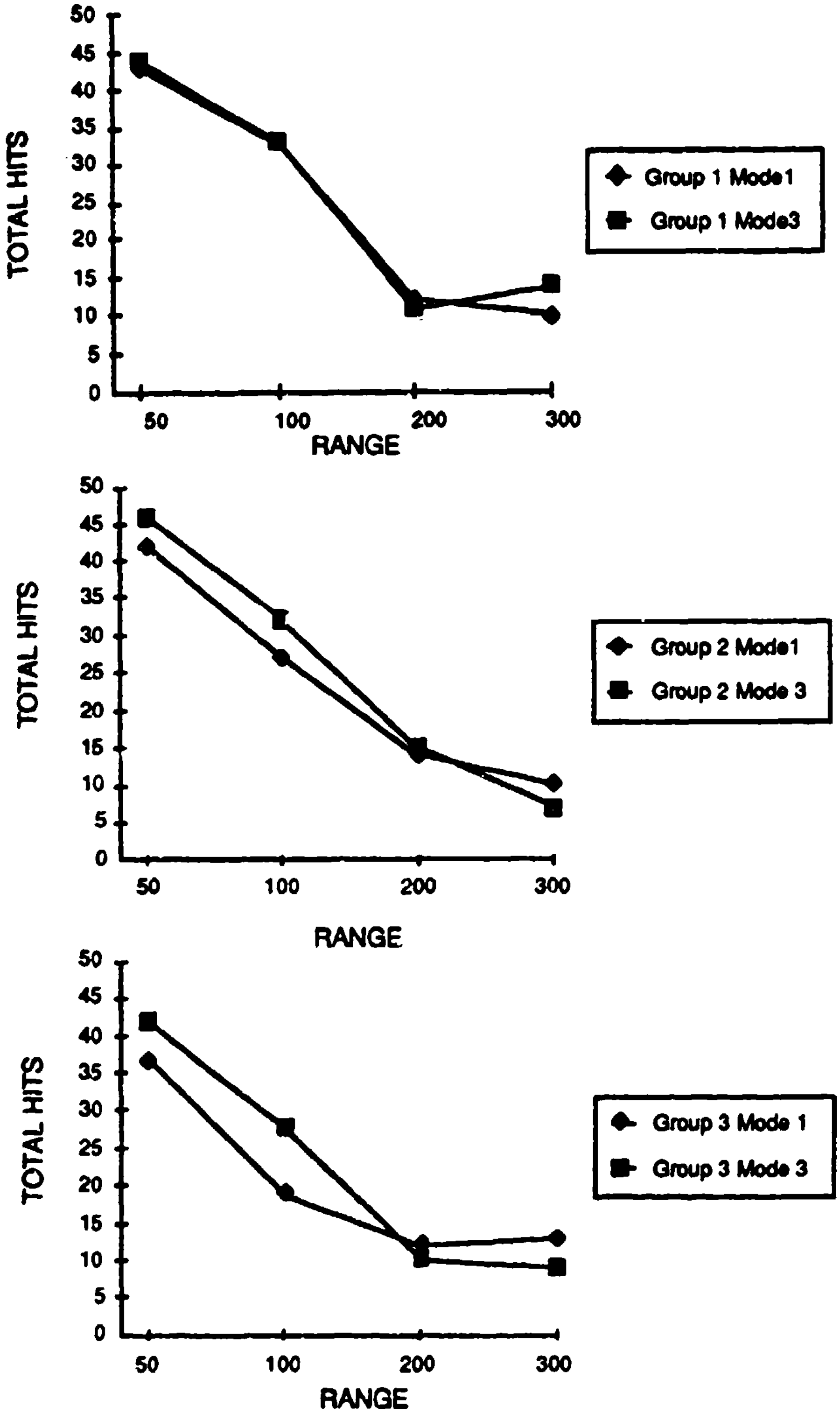


Figure 9. Hits for three targets presented for 5 seconds as a function of mode of fire (Mode 1 = semiautomatic, Mode 3 = three-round burst) and range for Competition Group 1 (top), Control Group 2 (middle), and Competition Group 3 (bottom).

effect of the two-target presentation was decreased at longer ranges. The Time x Target interaction ($F(4, 32) = 71.61$, $p<.0001$) indicates that the two target presentations were relatively more difficult at shorter exposure times.

Several three-way interactions failed to achieve significance. These included the Groups x Mode x Target ($F(4, 32) = 1.48$), Groups x Range x Time ($F(12, 32) = 1.74$), Groups x Range x Target ($F(12, 32) = 1.57$), Groups x Time x Target ($F(8, 32) = .52$), Mode x Range x Time ($F(6, 32) = .86$), Mode x Range x Target ($F(6, 32) = 1.37$), and Mode x Time x Target ($F(4, 32) = .33$) interactions. Among the significant three-way interactions were the Groups x Mode x Range ($F(6, 32) = 3.35$, $p<.011$), Groups x Mode x Time ($F(4, 32) = 2.68$, $p<.049$), and the Range x Time x Target ($F(12, 32) = 8.73$, $p<.0001$) interactions.

Among the four-way interactions, the interactions of Groups x Mode x Range x Target ($F(12, 32 = 1.60$) and Groups x Range x Time x Target ($F(24, 32) = 1.58$) interactions failed to achieve significance. The Groups x Mode x Range x Time ($F(12, 32) = 2.30$, $p<.029$) and Mode x Range x Time x Target ($F(12, 32) = 2.34$, $p<.027$) interactions were, however, significant.

For a thorough comparison of semiautomatic (one round per trigger pull) to burst mode (three rounds per trigger pull), a number of performance parameters must be addressed.

Targets hit per first trigger pull (FTP) considered any of the three projectiles of the first burst mode when totaling targets hit but did not count multiple hits on a target as more than one Hit. Over all ranges, 78.4% of targets hit in semiautomatic fire were FTP hits compared with 77% for burst fire. Of the 77% FTP hits for burst fire, 13.4% was the result of the second and third rounds of the FTP.

Additional trigger pulls were counted during any individual step of the target presentation scenario, provided no target was hit during the FTP. Any subsequent trigger pull, regardless whether it was fired at the same target or not, was an additional trigger pull. Ten percent more trigger pulls were taken in the burst mode than in semiautomatic mode. However, on a target-hit-per-trigger-pull basis, the result was a 23.2% hit probability for semiautomatic fire versus 22.0% hit probability for burst fire on this measure.

First round hit (FRH) per FTP considered only the first projectile of the three-round burst of the FTP on a target. Since detailed information about time of shot was recorded at the firing line, the residual velocity of the M855 round at the target was known, and the time stamp for target hits was known, each projectile of the burst for any trigger pull could be scored separately. At all ranges, the FRH/FTP of the burst mode was less than that observed during the semiautomatic mode of fire. The additional targets hit during the burst mode were the result of the second and third rounds of the burst as opposed to the first round. Over all ranges, semiautomatic fire produced 78.4% FRH/FTP compared to 63.6% FRH/FTP for burst fire. This is consistent with our earlier observation that 13.4% of targets hit during the FTP are the result of the second and third projectiles.

Through the use of the aim error calculation procedure described above, the aiming error associated with the first round of the FTP was determined. These data (see Figure 10) clearly indicate that a substantially increased aim error was associated with burst fire at all ranges. The aim error penalty associated with burst fire ranged from a high of 0.57 mil at 100 meters to a low of 0.24 mil at 300 meters.

The average elapsed time between target presentation and the first trigger pull hit for semiautomatic mode was 1.5 seconds, while the corresponding value for burst mode was 1.2 seconds. Note that a center target was presented in two-thirds of these cases (one target and three targets). The average reaction time was substantially increased if a large angular correction in weapon orientation was required, as was the case when two targets were presented. The low performance observed with 1.5-second exposure times may result from this particular exposure duration nearly equalling the time required to fire the first shot or burst.

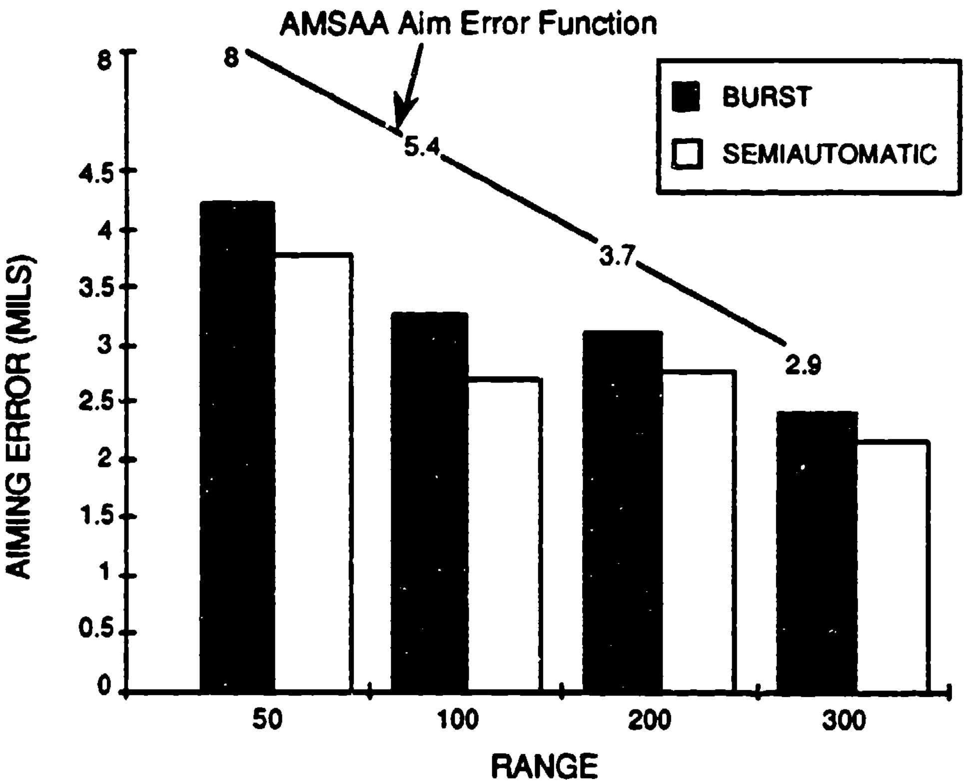


Figure 10. Aiming error in mils as a function of mode of fire and range.

DISCUSSION

The soldiers' training seemed to affect their performance in this experiment. In almost all scenarios in which multiple targets were presented and the first target fired upon was missed, the authors observed that the soldiers reacquired and reengaged the missed target, even if they had already acquired a second target. All the marksmanship instruction the soldiers received implied that it is more effective to re-acquire and reengage a missed target than to acquire and engage a new target. The effects of that training were apparent even under the influence of the task-induced and competition stressors. Although multiple targets were displayed and the soldiers were well aware of the short exposure times, the firing technique emphasized during training was strictly followed.

When firing in burst mode, the soldiers appeared to fire the first round faster and tolerate a larger aim error to do so. The average time to fire data, which is the time to discharge the first round after a target is detected given that there is a target hit, was 1.2 seconds for burst mode, as opposed to 1.5 seconds for the semiautomatic mode. Since the sight picture presumably did not change and targets were no easier to acquire, a plausible explanation for this increased firing quickness is that the soldier perceived the advantage of burst fire as additional rounds dispersed around the target which would compensate for their decreased aiming accuracy.

It was expected that because of the weapon climb when firing burst mode, it would be more difficult to re-acquire the target and obtain a sight picture for firing subsequent bursts. This did not seem to be the case. In burst mode, a greater number of trigger pulls were recorded than in semiautomatic mode, with a similar percentage of targets defeated as in semiautomatic mode. One reason for this is that the time to fire in burst mode was 0.3 second less than in semiautomatic mode, perhaps attributable to pointing rather than aiming the weapon. This more rapid firing created more engagement opportunities. These additional opportunities may have operational significance.

Several examples of targets being hit by more that one projectile of a burst (strikes) were recorded. These data are presented in Figure 11. Although multiple strikes are probably desirable, they may not outweigh the disadvantage of the increased combat load which would be required if burst mode were relied upon extensively. The added weight because of additional ammunition fired just for the scenarios presented in this experiment is 3.66 pounds per soldier, based on published weights for M855 ammunition (Department of Defense, 1981). When questioned, the soldiers made it clear that moderate improvements in performance would not justify tripling their ammunition load. The soldiers thought that combat load should be decreased instead of increased.

As was stated previously, the mean extreme spread of a three-round burst for the M16 would have to be about 8 milliradians to optimize hit probability across the target ranges used in this experiment for the aiming error function offered by AMSAA and accepted by the analytical community. The aiming error is a negative exponential function of range whose values vary from an 8-mil standard deviation at 50 meters to 2.9 mils at 300 meters, whereas corresponding experimental values are approximately 4.2 mils and 2.3 mils, respectively. Note that the burst dispersion of the M16A2 is 22 mils, and the M16A2 equipped with the NWSC No. 1 muzzle device is 16 mils. AMSAA predictions showed that little improvement could be expected from a system with a 16-mil mean extreme spread except at close range. The only significant improvement in targets hit found in this experiment was at 50 meters, confirming this prediction. Also, this experiment was unable to generate aim errors as large as those of the AMSAA function.

Although the competition generated in this field experiment (the SS study) produced significant stress responses, as documented in the next two chapters, it did not result in overall performance differences between Competition and Control Groups in terms of targets hit.

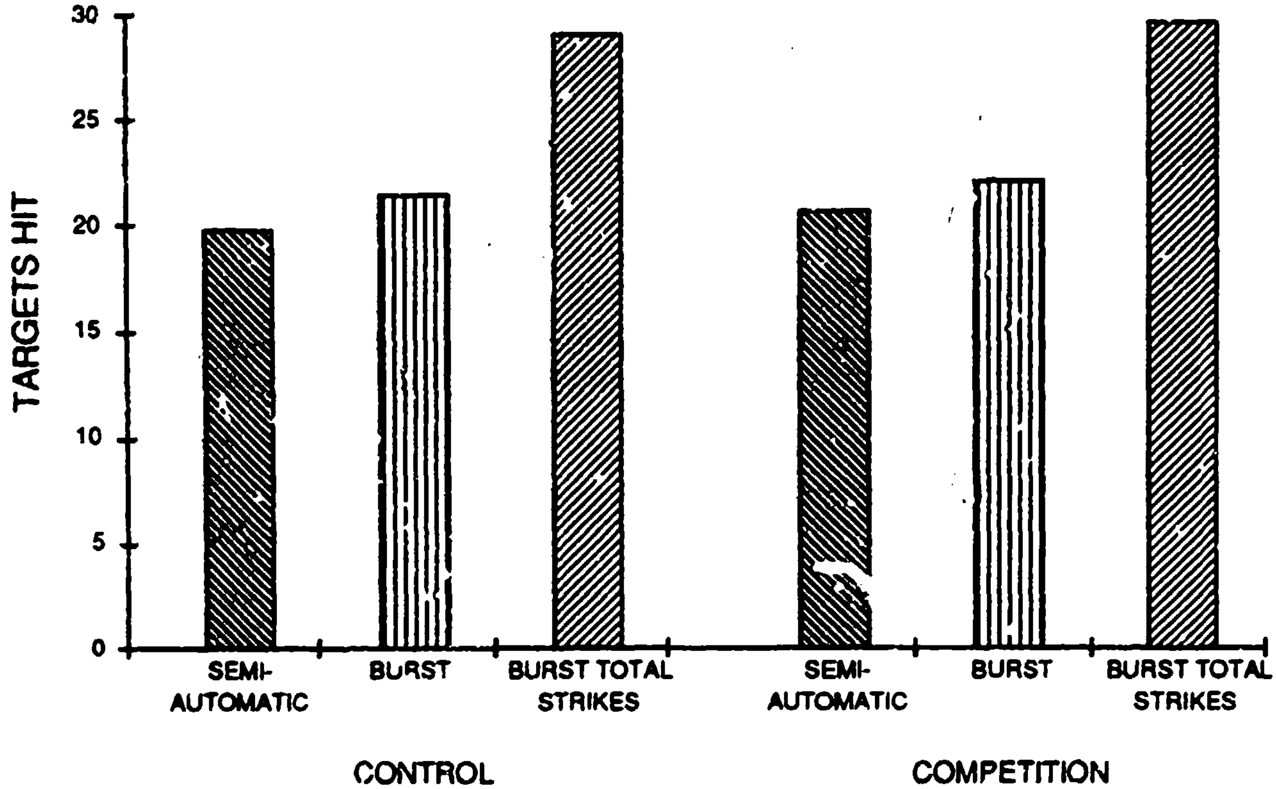


Figure 11. Targets hit as a function of group and mode of fire. (BURST hits include targets struck by one or more projectiles in a burst. BURST-TOTAL STRIKES counts multiple hits within the same burst on the same target.)

CONCLUSIONS

In this chapter, we have reported that (a) competition failed to change overall group shooting performance; (b) aim error was greater in burst mode than in semiautomatic mode; (c) the aim errors generated were smaller than those accepted by the analytical community as expected during combat stress, particularly for short ranges, although this discrepancy decreased as range increased; (d) as predicted, a relatively large burst dispersion coupled with a relatively low aim error did not improve burst mode beyond semiautomatic fire; and (e) as expected, target range, time of exposure, and the number of targets presented influenced hit probability.

CHAPTER 3

HORMONE RESPONSES TO COMPETITIVE MARKSMANSHIP

(G. A. Hudgens, L. T. Fatkin, J. P. Torre, Jr., J. M. King,
S. E. Slager, R. T. Chatterton, Jr.)

INTRODUCTION

The HEL Salvo Stress (SS) study was conducted as a field experiment supporting two principal purposes: (a) the evaluation of competition as an effective component in a methodology to produce a known level of stress in soldier-equipment performance testing; and (b) the generation of performance data on the soldier-M16A2 rifle system in support of the projected Advanced Combat Rifle (ACR) field test. The physiological data described in this chapter and the psychological data described in the following chapter were obtained as components of the competition stress evaluation. These data were collected to help determine whether the competition generated was stressful to the soldiers and, if so, to help determine how stressed the soldiers were and how the level of stress related to their performance.

Since the introduction of the concept of stress by Selye (1936), the primary indicators and validators of stress responses have been physiological. They have involved the measurement of the catecholamines, primarily adrenaline and noradrenaline, which are secreted as the result of activity of the sympathetic adrenal medullary system, and the measurement of corticosteroids, such as cortisol, which are secreted as the result of activity of the pituitary-adrenocortical system. Selye's original concept, which has been predominant in the field ever since, implicated these responses as <u>the</u> responses to be expected in all cases when an organism is stressed (his "nonspecificity" concept).

The half-century dominance of Selye's concept has caused confusion in the area and has, according to Mason (1971), stifled further research into stress mechanisms. From both clinical and experimental stress data came evidence of considerable individual variability as to the nature of stimuli required to elicit a response and the degree of (catecholamine or corticosteroid) response. Nevertheless, Selye's views were [illegible] strongly accepted that few considered entertaining alternate theories.

During the last 3 decades, considerable experimental and clinical data have accumulated which do not support Selye's early notions; these data have led some investigators to new theoretical concepts to account for much of the observed stress response variability (Mason, 1974, 1975; Seggie & Brown, 1982). While Mason addressed stressor-specific response profiles and Seggie and Brown addressed pathway-specific stress responses, both formulations were based on recent advances in knowledge about the variety of different hormonal and other physiological responses regulated by a variety of different control pathways. Thus, both theoretical formulations predict that different kinds and levels of stressors interact with personal characteristics (e.g., personality or memory of past experience) to yield stressor-specific response profiles.

In practical terms, the preceding means that we need to know (regarding the ability to evaluate competition as a stressor in this study) (a) which physiological and psychological response indices are likely to be responsive to the stressor in question, and (b) how these responses are likely to be modified by measurable personal variables such as personality. The HEL basic research program, "Combat Stress Mechanisms and Effects on Performance," is designed to provide this knowledge.

Through a current contractual effort with Northwestern University and a prior effort with the Veterans' Administration West Side Medical Center, the program seeks to obtain extensive physiological and psychological response data in a number of protocols investigating different kinds and intensities of stressful situations. Physiological stress-response measures include the more traditional ones, the catecholamines (epinephrine and norepinephrine) and the adrenocortical hormone cortisol, and other hormones more recently shown to be responsive to various stressors (growth hormone, luteinizing hormone, testosterone, and prolactin). In addition, the program is now including in its battery two opioid peptides (beta-endorphin and Met-enkephalin), recently shown to be part of the body's analgesic response to stress. These opioid peptides represent an extensive variety of such responses to stress that promise to provide new insights about how the body handles stress. While many of the analgesic responses occur in response to acute stressors, their more long-term effects suggest that their role may be more important to the body's handling of chronic stress. In the same protocols, psychological assessments are made of the subjects' personality traits, coping mechanisms, and perceptions of how stressed they feel at different times. The specific goals of the program are (a) to verify the notion that different kinds and levels of stress, interacting with personal variables, yield unique physiological and psychological response profiles; (b) to create, in effect, a collection of such profiles against which other stressors can be evaluated; (c) to determine which combination of physiological and psychological indices might be most efficiently and effectively used to measure stress experienced by subjects in future efforts; and (d) to develop a data base that will allow modeling of combat stress by including data for more combat-like stressors and by extending the investigations to include the effects of multiple and chronic stressors.

Because the current effort (i.e., the HEL SS study) was accomplished in a relatively early stage of the basic research program just described, the evaluation of competition as a stressor in this effort will necessarily be limited. Data derived from low and moderate level stressors are nearly complete for several stressors in the basic program. However, collecting data on people who are experiencing truly high levels of stress (e.g., when life, limb, ego, or career are threatened) has proved to be quite difficult. The necessary voluntary cooperation of the people involved has been quite limited. Consequently, the authors' current ability to evaluate new stressors relative to the others for which data are adequate appears to be limited to low and moderate stress levels. If the stress that can be generated by competition proves to be within the moderate range, an evaluation should be valid. If it proves to be more stressful, the evaluation will suffer from the lack of comparative data for intense stress. A certain advantage of this study occurring early in the program, however, is that the current data can be incorporated into the growing data bank to provide more profile data on different kinds of stress, to improve and extend the metric for use in future efforts.

To summarize, the current effort represents an initial attempt to evaluate the use of competititon as one component of a methodology for generating stress. The profile of physiological and psychological responses obtained in this effort will be compared with those obtained in other protocols of the basic research program. It is predicted that the profile of responses obtained for the stress of competition in this effort will be characteristic of a moderate to high stress profile.

METHOD

Subjects

Subjects were described in Chapter 1.

Procedures

General procedures were described in Chapter 1.

Ten blood samples were obtained by an indwelling catheter from each of the 60 subjects. Samples 8 through 10 were missed for one subject when his vein collapsed, and difficulty was experienced in establishing a new catheterization. Once the catheters were established and secured in a comfortable position in the rifle-support arm for each subject, there were few problems, and none of the subjects reported any interference with firing. Samples 1 through 4 were obtained on the second day of familiarization firing (baseline day) before firing. The times of collaction were set to correspond to the first four times of collection on the subsequent record-fire day (Day 3); consequently, a control interval of approximately 15 minutes was allowed between subjects to correspond to the anticipated record fire interval for each subject (based on pilot tests). Blood samples were then staggered relative to each subject's 15-minute anticipated firing interval, so that on baseline day, samples were obtained 90 minutes (Sample 1), 60 minutes (Sample 2), and 15 minutes (Sample 3) before and 15 minutes (Sample 4) after that control interval. On record-fire day, samples were obtained 90 minutes (Sample 5), 60 minutes (Sample 6), and 15 minutes (Sample 7) before the anticipated interval and 15 minutes (Sample 8), 60 minutes (Sample 9), and 120 minutes (Sample 10) after completion of record firing. The difference in the number of samples obtained on baseline versus record-fire day was attributable to a limitation of 10 samples (200 milliliters [ml]) of blood per subject. It was deemed more important to obtain good post-firing recovery data for record-fire day than to have all sampling times matched during the 2 days. A generalized time chart for procedures used in the protocols referred to in this chapter is provided in Chapter 4.

Three blood-sampling stations and a blood-preparation laboratory were set up in a mobile laboratory about 20 feet immediately behind the firing line. A waiting area was located in a large tent about another 20 feet behind the laboratory. Each subject was assigned a particular station to visit for all blood procedures. Each station was operated by a qualified and experienced phlebotomist under the supervision of a registered nurse. Insertion of the catheters with heparin locks was begun at 0700 hours on baseline and record-fire days; blood drawing began at 0730. Because times were staggered to allow 15-minute intervals for firing, blood drawing necessarily extended for some subjects into the early afternoon on baseline day and into the middle afternoon on record-fire day. Control for time of day was maintained by taking samples at the same times on both days for each subject. Thus, each subject served as his own control. Since the experimental and control conditions were always conducted with 20 subjects following the identical time schedules, time of day was also controlled for across groups.

Upon arrival at the test site before 0700, the subjects reported to the waiting area tent. Beginning at 0700, the subjects were sent in order to their appropriate blood-drawing stations for insertion of the catheters. They then reported back to the waiting area where they remained, except when sent back to the laboratory for blood draws, on baseline day. Familiarization firing on that day did not begin until all blood draws were completed. On record-fire day, the routine was much the same. When the first subject was to perform record firing, the subjects were told they could spend their waiting time either in the stands behind the firing line watching those firing or in the waiting area tent. Subjects in the Competition Group were encouraged to spend their waiting time in the stands watching their teammates. Catheters were removed immediately after Sample 4 on baseline day and after Sample 10 on record-fire day. Drinking water was available at all times in the waiting area, in the laboratory, and at the observation stands. Subjects were encouraged to drink plenty of water to keep from becoming dehydrated and to facilitate the blood drawing. They were also instructed to avoid consuming alcohol or caffeine on either day before or during blood drawing and to eat and drink nothing except water after breakfast (at about 0600). They were allowed to eat after the catheters were removed.

Figure 12 shows one of the subjects having a blood sample drawn. At each sampling time, 20 ml of blood were obtained. Half of each sample (10 ml) was immediately put into a 12-ml chilled glass centrifuge tube containing 0.16 ml of a neutral solution containing 20 mg of [Ethylenebis(oxyethylenenitrilo)] tetraacetic acid (EGTA) and 12 mg of glutathione for subsequent assay for hormones (cortisol, prolactin, testosterone, growth hormone, luteinizing hormone) and catecholamines (epinephrine, norepinephrine). The remaining half of each sample (10 ml) was put into a 12-ml chilled plastic centrifuge tube containing 0.16 ml of a neutral solution containing 20 mg of EGTA and 0.1 mg of aprotinin (obtained from the Sigma Chemical Company, St. Louis, Missouri) for subsequent assay for opioid peptides (Met-enkephalin, beta-endorphin). Samples were kept on ice until transferred to the laboratory for further preparation which took place within 15 minutes. Upon transfer to the laboratory, samples were placed in a refrigerated centrifuge to obtain the plasma. Two and one-half-ml aliquots of plasma were added to vials pre-labeled with identification numbers and codes for the various assays to be performed. Those vials designated for the Met-enkephalin assays contained 100 µl of glycine buffer (1.6 grams of glycine per 100 ml of 1 N [normal solution] hydrochloric acid [HCl]). The sealed vials of plasma were immediately frozen and held on dry ice. They were packed and shipped on dry ice at the end of each week's testing to Northwestern University for assay. Details about the procedures used in assaying the samples are presented in Appendix D.

Data Reduction

Data reduction was accomplished using Versions 3 and 4 of the statistics software package SYSTAT (The System for Statistics, Wilkinson [1987], [1988]). The following data-analysis modules were used as appropriate: STATS (univariate statistics), MGLH (Multivariate General Linear Hypothesis, multivariate statistics), CORR (correlation procedures), and CLUSTER (cluster analysis).

RESULTS

At the time this report was prepared, assay results and data analyses were complete for the hormones cortisol, luteinizing hormone (LH), prolactin (PRL), growth hormone (GH), and testosterone (T). Assay results for the catecholamines and opioid peptides were not complete and will be presented in later reports.

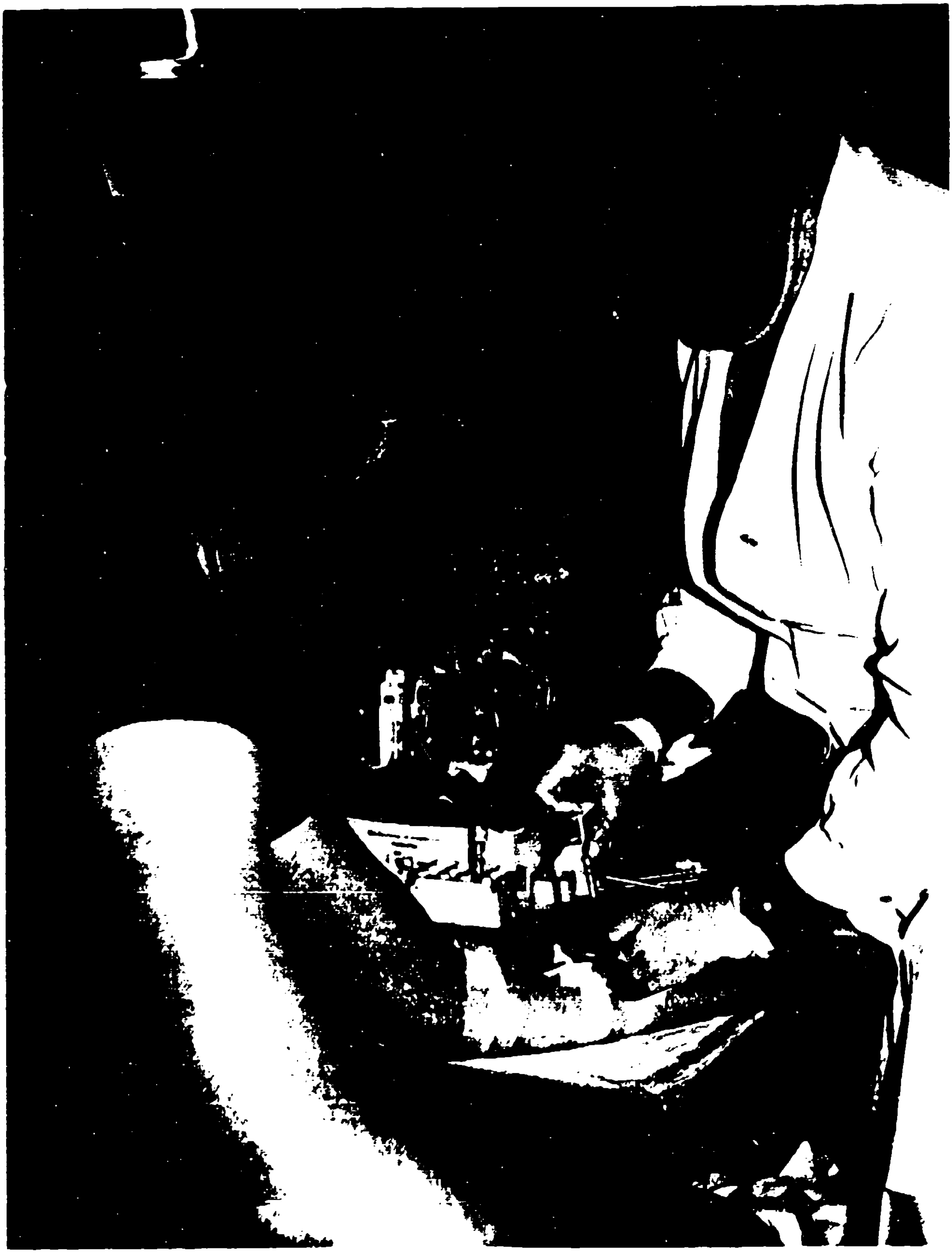


Figure 12. Soldier having blood sample drawn through indwelling catheter.

Data Reduction

Because different numbers of blood samples were obtained on baseline and record-fire days, the appropriate approach to analyzing the hormone data was complicated. In studies when the time points for 2 days are matched, one commonly used method of analysis involves considering each subject as his own control; the data are then analyzed for changes in hormone response from one day to the next. In the present study, change values were computed for each hormone by subtracting baseline day values from record-fire day values for each of the four common time points. While analysis of the hormone change values for the treatment groups in this study would yield stronger conclusions about treatment effects than analysis of days' data would separately, such analysis can result in the loss of potentially important information. The stress model employed in the HEL stress program predicts different patterns of response for different kinds and levels of stress during extended anticipatory and recovery periods surrounding stress events. For instance, the model hypothesizes (Hudgens, Torre, Chatterton, Wansack, Fatkin, & DeLeon-Jones, 1986) that the duration of stress response relates to the intensity of stress experienced. Because of the exploratory nature of this study, and so that information important to the stress program could be derived, the hormone data were analyzed by days separately as well as by change values from baseline to record-fire day.

An initial multivariate analysis of variance (MANOVA) was conducted for baseline day data. The design was Groups (2) x Hormones (5) x Time Points (4). Since the three-way interaction effect was highly significant as shown by the multivariate test statistics (Wilks' $\lambda = .574$, $F=2.903$; $df=12,47$; $p=.004$), subsequent MANOVAs were conducted for each hormone using Groups (2) x Time Points (4) designs.

Similarly, an initial MANOVA was conducted for record-fire day data. The design was the same as for baseline day except that there were six time points. The multivariate test statistics for the three-way interaction (Wilks' $\lambda = .511$, $F=1.815$; $df=20,38$) yielded a $p=.056$, which, because of the exploratory nature of this research and the conservative nature of MANOVA, was considered sufficient to justify conducting subsequent MANOVAs for each hormone as was done for the baseline day data.

A MANOVA was also conducted in the same manner for the hormone change values computed as described above. The design was the same as for the two days separately with the number of time points limited to the four common to the two days. Again, the multivariate test statistics for the three-way interaction (Wilks' $\lambda = .664$, $F=1.939$; $df=12,46$) yielded a $p=.054$, which was considered sufficient to justify conducting subsequent MANOVAs for each hormone.

The results of the subsequent MANOVAs are described below by hormone. Post hoc tests were done using the Tukey-Kramer modification of the Tukey Honestly Significant Difference (HSD) test, which was available in the SYSTAT STATS module, and which was appropriate in comparisons with unequal numbers of observations (Wilkinson, 1988, p. 709).

Figures 13 through 27 present the mean responses (+SEM [standard error of the mean]) for the five hormones at the 10 sampling time points and the mean change values (±SEM) over four time points for the subjects during competitive conditions and for the control subjects.

Occasional discrepancies in degrees of freedom reported are attributable to missing data points for one subject which was the result of failure to obtain blood samples for that subject when his vein collapsed after firing on record-fire day.

Cortisol

Figure 13 presents results for baseline day and Figure 14 for record-fire day. For baseline day, the MANOVA yielded no significant differences because of group treatment effects. For record-fire day, the Groups x Time Point interaction was significant (Wilks' λ = .804; F=2.58; df=5,53; p=0.037; univariate F=3.65; df=5,285; p=.003). Post hoc tests for this interaction effect were conducted using the modified Tukey HSD test which yielded a critical value ($CV_{.01}$) of 18.99 for α=0.01 and $CV_{.05}$=14.45 for α=0.05 for group comparisons across time points. For testing within-group differences across time points, $CV_{.01}$=20.12 for α=0.01 and $CV_{.05}$=17.04 for alpha=0.05 for the Competition Group; and $CV_{.01}$=28.45 for α=0.01 and $CV_{.05}$=24.10 for α=0.05 for the Control Group. The interaction effect is best described with reference to within-group differences over time. While the Control Group cortisol response level showed no significant differences between any two time points, the cortisol level for the Competition Group 15 minutes after firing for record was significantly elevated over the levels at all other time points (p<.01).

The change data (see Figure 15) show a rather straightforward picture for the relative cortisol response changes over the four time points common to baseline and record-fire days. Before the fire-control interval, the groups did not differ significantly in their changes in cortisol level from baseline to record-fire days ($CV_{.05}$=16.78; p>.05). At +15 minutes after the interval, however, the Competition Group showed a significantly greater increase ($CV_{.01}$=22.06; p<.01) than did the Control Group.

Luteinizing Hormone (LH)

Figure 16 presents data for the baseline day, Figure 17 for the record-fire day, and Figure 18 for the change from baseline to record-fire day. For baseline day, the MANOVA showed a significant groups main effect with the Competition Group having higher overall level of LH (F=5.72; df=1,58; p=.02). The same significant effect was obtained for the record-fire day where the Competition Group had higher LH over the six time points (F=6.06; df=1,57; p<.02). No significant groups by time point interactions were obtained for either day. The MANOVA on LH change values yielded no significant effects involving groups.

Prolactin (PRL)

Figure 19 presents data for the baseline day and Figure 20 for the record-fire day. A MANOVA on the baseline day yielded a significant Groups x Time Point interaction effect (Wilks' λ = .717; F=7.38; df=3,56; p<.001; univariate F=3.80; df=3,174; p=.01). This effect can be interpreted with regard either to group differences at different time points or to different group changes in response between time points. The Competition Group showed a higher PRL level than the Control Group at -60 minutes ($CV_{.01}$=0.80; p<.01) and at +15 minutes ($CV_{.05}$=0.61; p<.05); both groups showed significant decreases in PRL early in the day; the Control Group PRL level dropped between -90 and -60 minutes ($CV_{.05}$=0.92; $CV_{.01}$=1.10; p<.01), and the Competition Group PRL

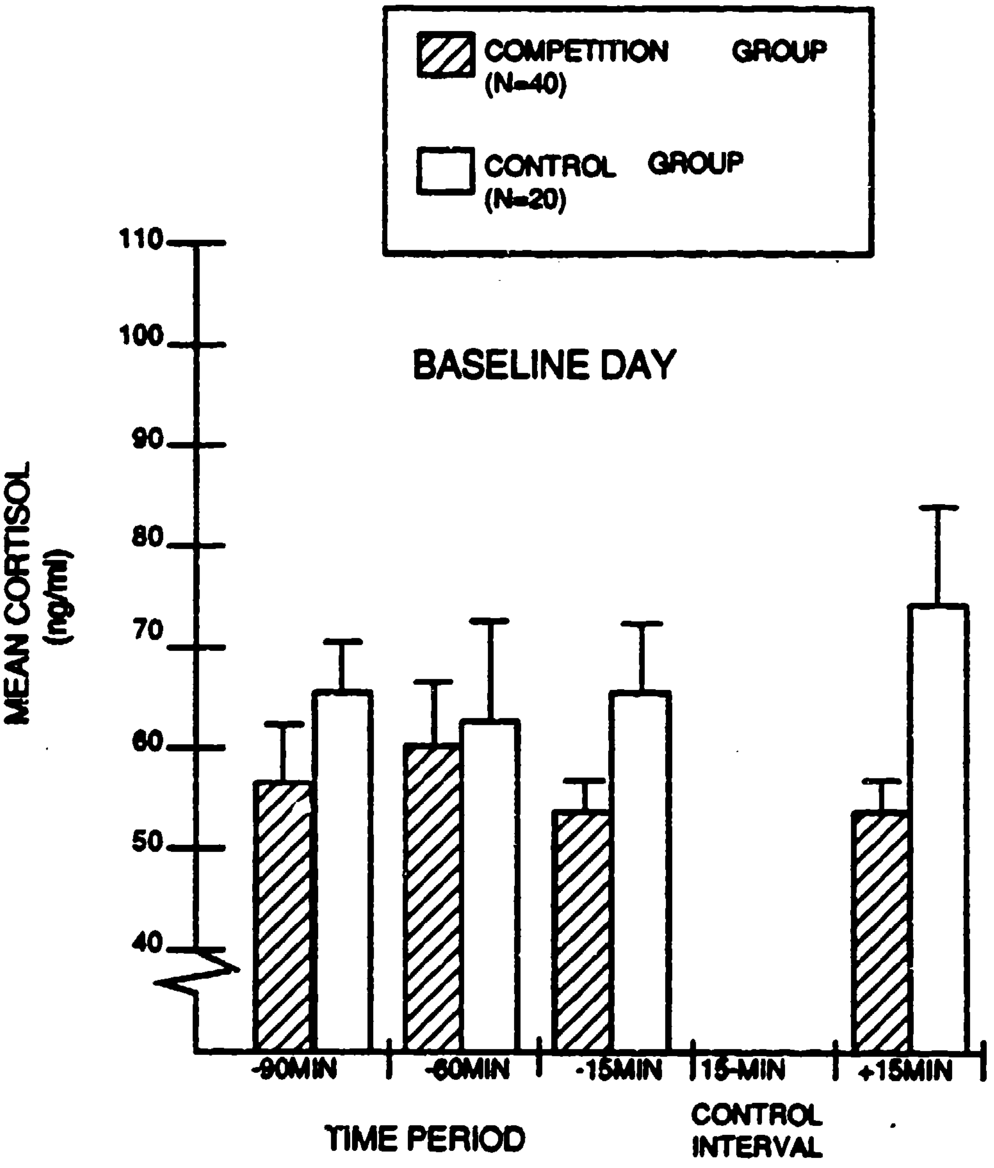


Figure 13. Mean cortisol levels for Competition and Control Groups at four sampling times on baseline day.

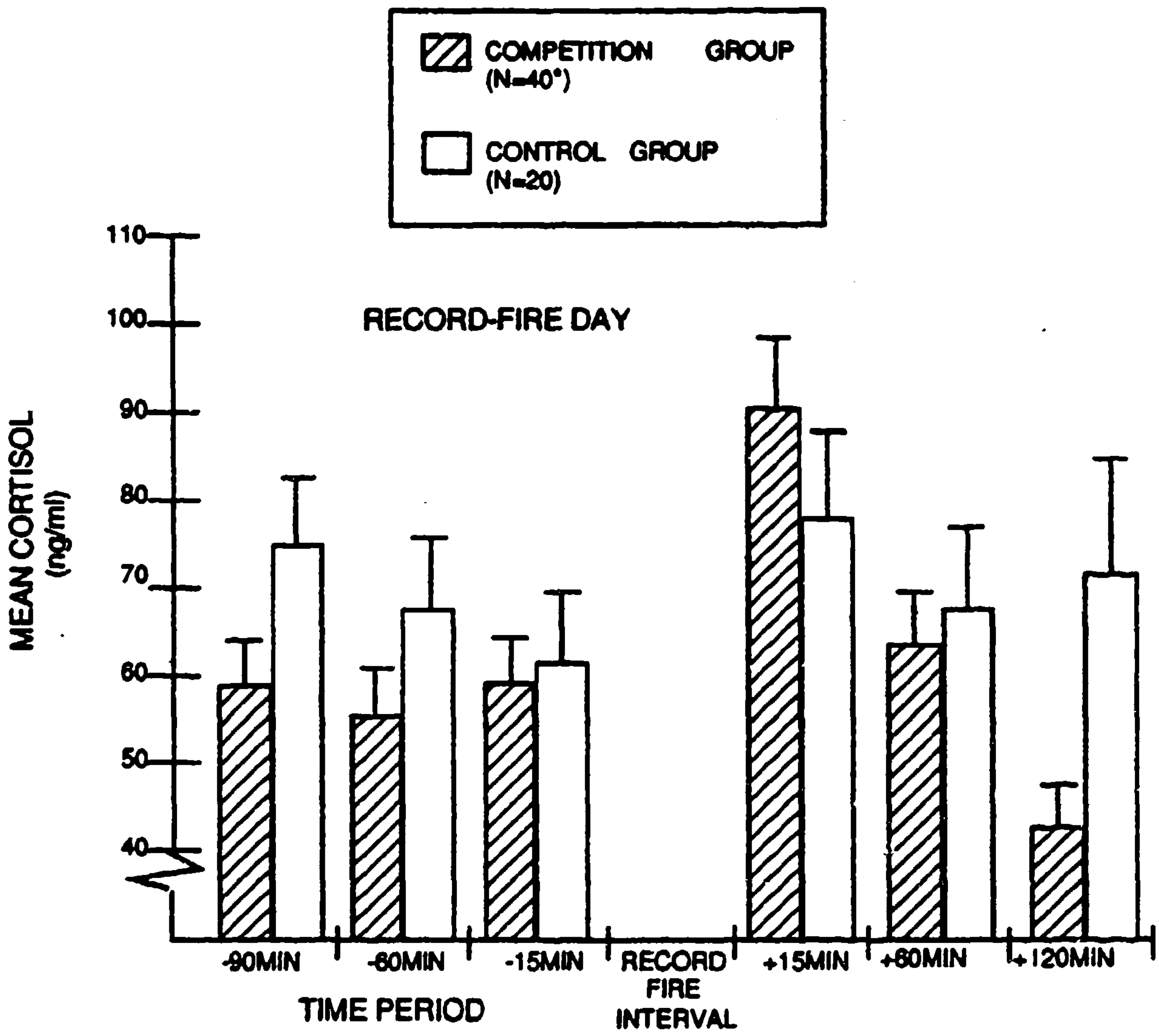


Figure 14. Mean cortisol levels for Competition and Control Groups at six sampling times on record-fire day (*N=39 post firing because of catheter failure in one subject).

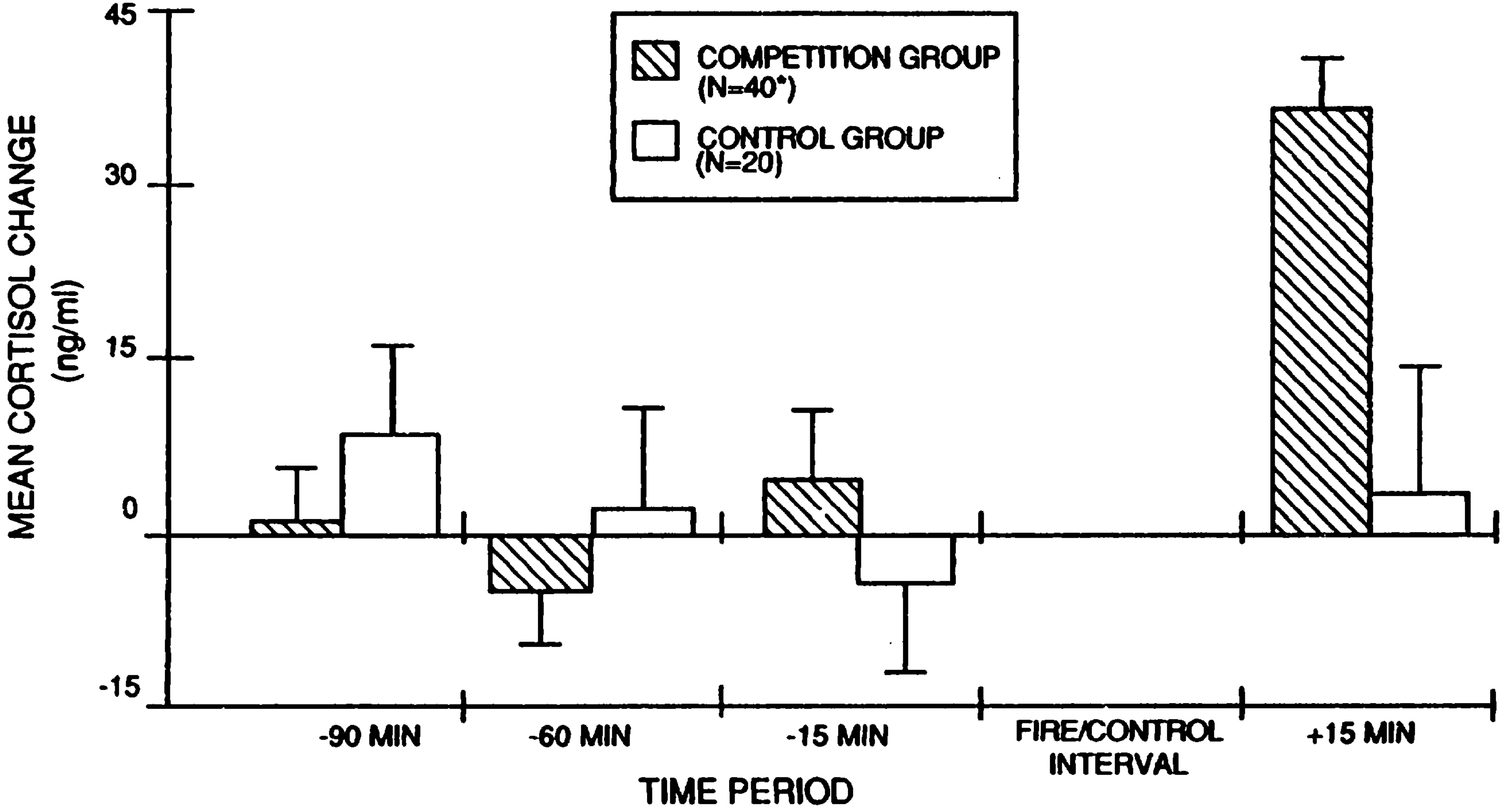


Figure 15. Mean change in levels of cortisol for Competition and Control Groups for the four sampling times common to baseline and record-fire days (Change=record-fire level - baseline level. *N=39 post firing because of catheter failure in one subject.)

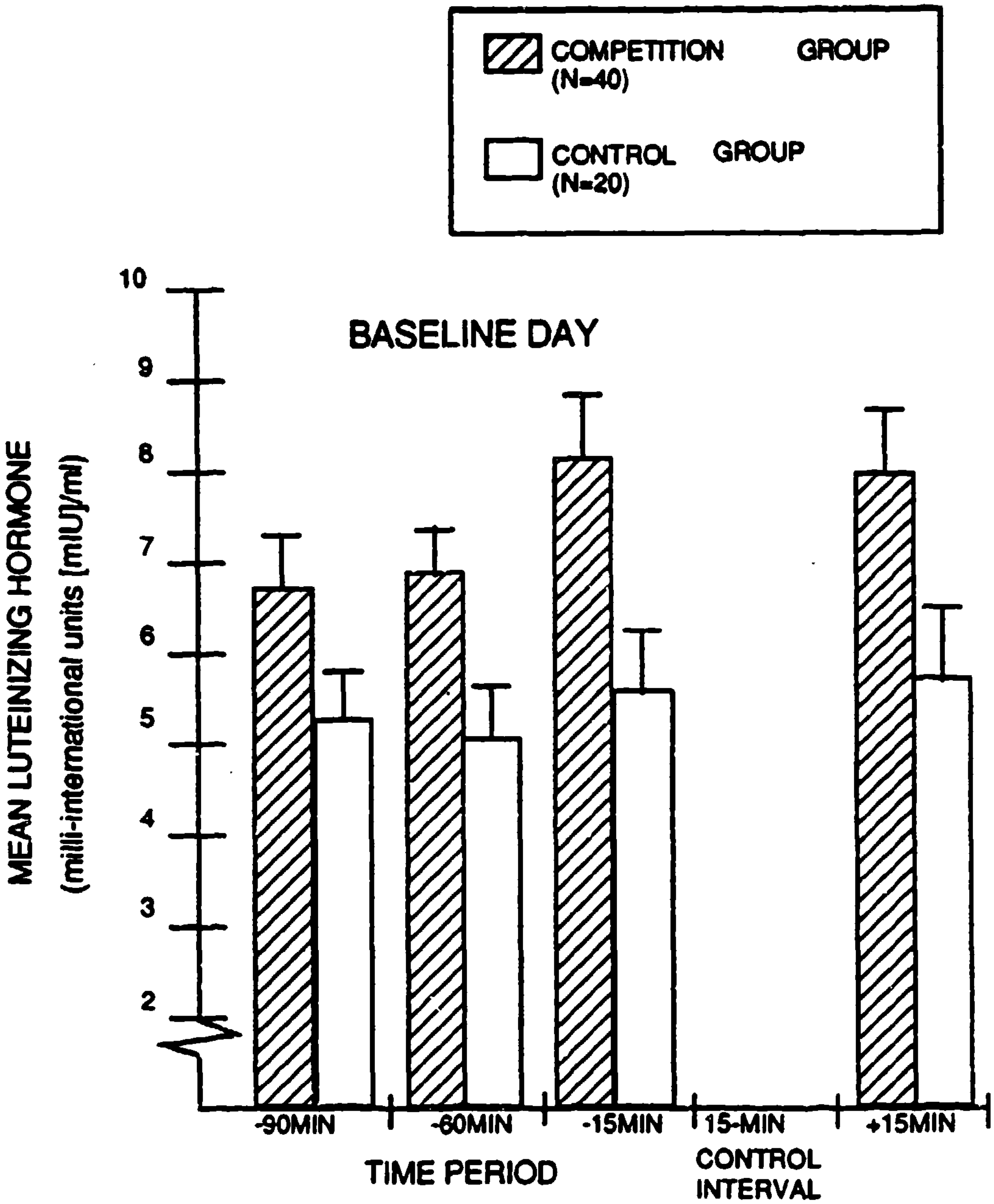


Figure 16. Mean luteinizing hormone levels for Competition and Control Groups at four sampling times on baseline day.

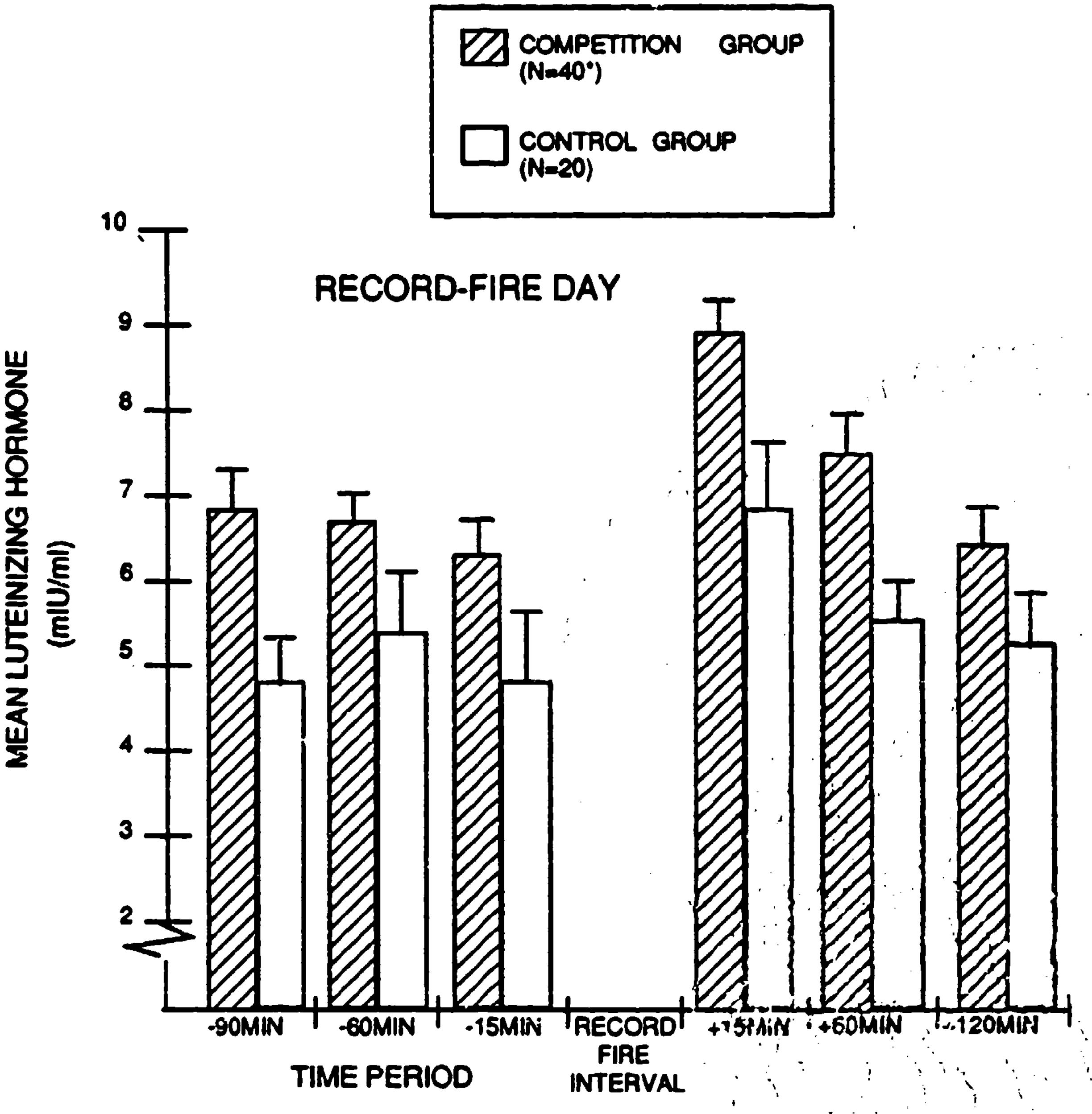


Figure 17. Mean luteinizing hormone levels for Competition and Control Groups at six sampling times on record-fire day (*N=39 post firing because of catheter failure in one subject).

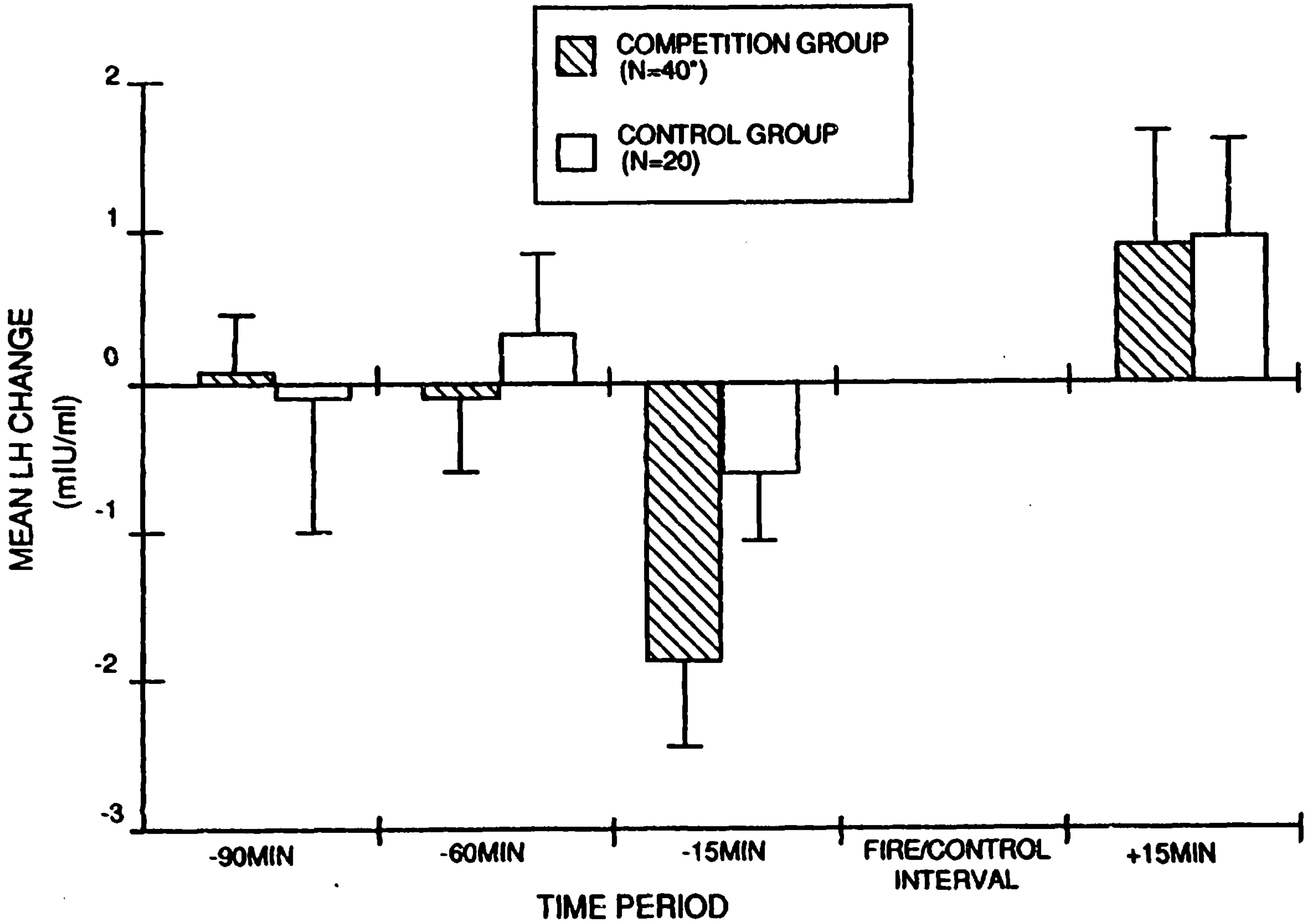


Figure 18. Mean change in levels of luteinizing hormone for Competition and Control Groups for the four sampling times common to baseline and record-fire days (Change = record-fire level - baseline level. *N=39 post firing because of catheter failure in one subject.)

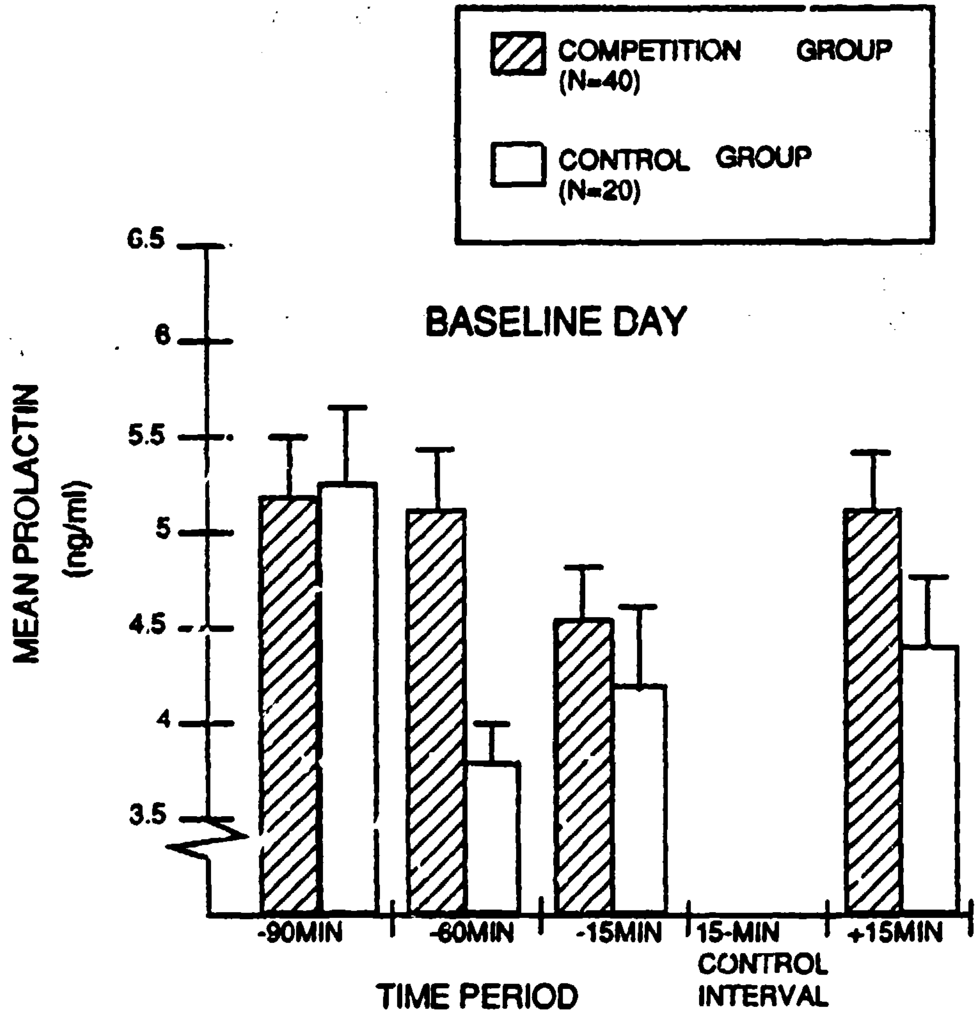


Figure 19. Mean prolactin levels for Competition and Control Groups at four sampling times on baseline day.

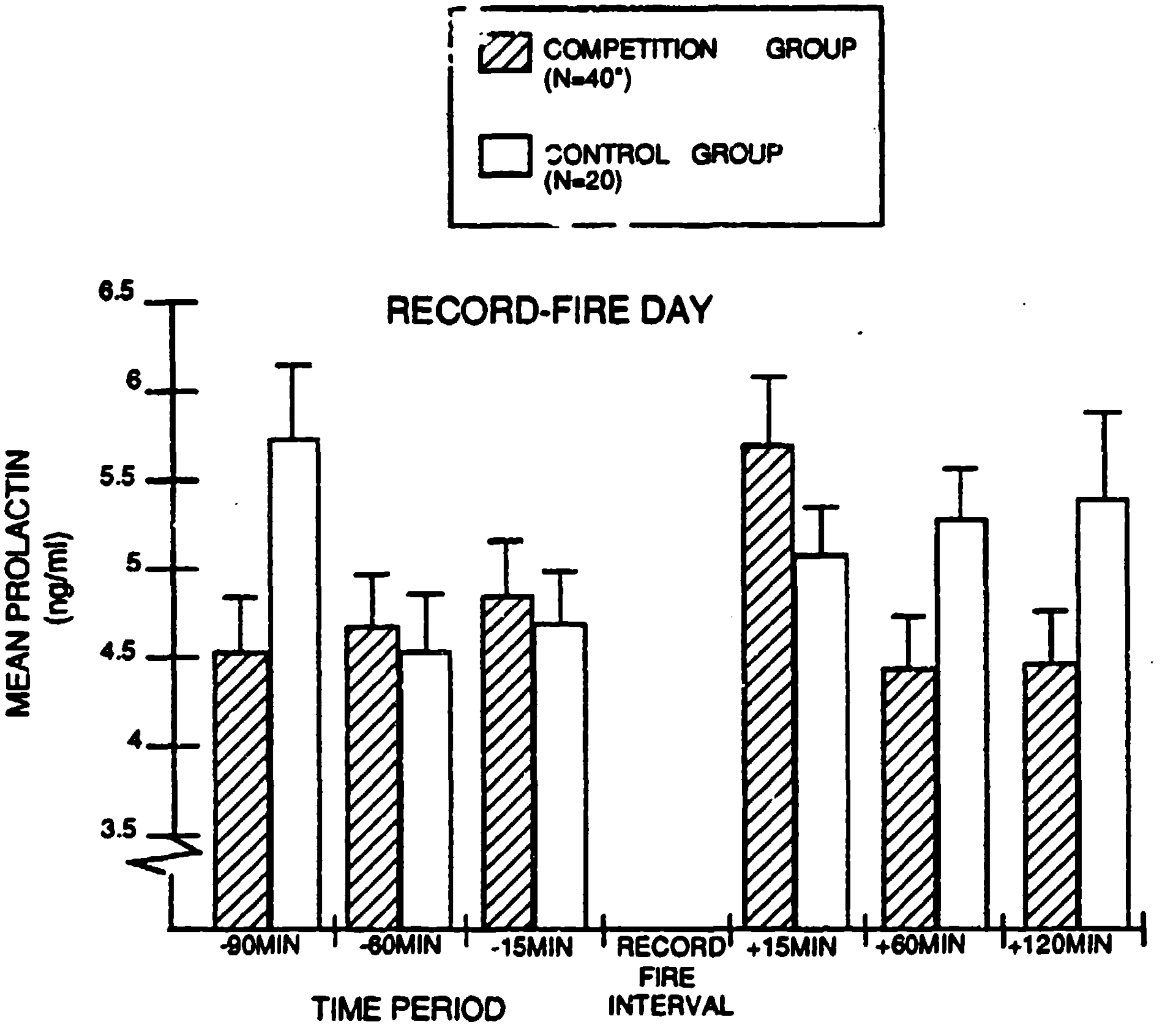


Figure 20. Mean prolactin levels for Competition and Control Groups at six sampling times on record-fire day (*N=39 post firing because of catheter failure in one subject).

level dropped significantly ($CV_{.05}$=0.65; $CV_{.01}$=0.78; $p<.05$) between -60 and -15 minutes. The MANOVA on the record-fire day also yielded a significant Groups x Time Point interaction effect (Wilks' λ = .716; F=4.20; df=5,53; p=.003; univariate F=7.13; df=5,285; $p<.001$). The groups differed significantly at -90 minutes ($CV_{.01}$=.87; $p<.01$), at +60 minutes ($CV_{.05}$=.66; $p<.05$), and at +120 minutes ($p<.01$). The Control Group showed a significant drop in PRL from -90 to -60 minutes ($CV_{.05}$=1.10; $CV_{.01}$=1.30; $p<.05$). The Competition Group showed a significant rise in PRL from -15 to +15 minutes ($CV_{.05}$=.78; $CV_{.01}$=.92; $p<.05$) after firing and a subsequent drop to pre-firing levels by +60 minutes ($p<.01$).

A MANOVA on change data for PRL from baseline to record-fire day (see Figure 21) yielded no significant group treatment effects.

Growth Hormone (GH)

Baseline day data are presented in Figure 22 and record-fire day data in Figure 23. For baseline day, the MANOVA showed a significant groups main effect with the Competition Group displaying a significantly lower level of GH over time (F=5.70; df=1,58; p=.02). The MANOVA on record-fire day yielded a significant Groups x Time Point interaction effect (Wilks' λ = .814; F=2.42; df=5,53; $p<.05$; univariate F=3.18; df=5,285; $p<.01$). The Competition Group mean GH was lower ($CV_{.05}$=2.67; $p>.05$) than the Control Group mean at the three pre-firing time points, significantly higher at +15 minutes after firing ($CV_{.01}$=3.51; $p<.01$), and lower ($p>.05$) again by +120 minutes. Between -15 minutes and +15 minutes, the Competition Group showed a highly significant increase in GH level ($CV_{.05}$=3.15; $CV_{.01}$=3.72; $p<.01$), while the Control Group showed a decrease in GH ($CV_{.05}$=4.46; $p>.05$). After firing, the Competition Group showed a highly significant decrease back to pre-firing levels between +15 and +120 minutes ($p<.01$), while the Control Group stayed within pre-firing levels.

A MANOVA on GH changes from baseline to record-fire day (see Figure 24) yielded a marginally significant Groups x Time Point interaction effect (Wilks' λ = .891; F=2.23; df=3,171; p=.095; univariate F=3.32; df=3,171; p=.021). The groups differed only at +15 minutes ($CV_{.05}$=3.29; $CV_{.01}$=4.33; $p<.01$).

Testosterone (T)

The groups did not differ significantly in T levels at any of the 1) time points, nor did their patterns of response differ significantly over those time points. The data for baseline and record-fire days are shown in Figures 25 and 26.

The mean group changes in T are shown in Figure 27. The MANOVA of the T change data yielded a significant groups main effect (F=5.54; df=1,57; p=.02) reflecting the overall decrease in T for the Competition Group from baseline to record-fire day compared with Controls.

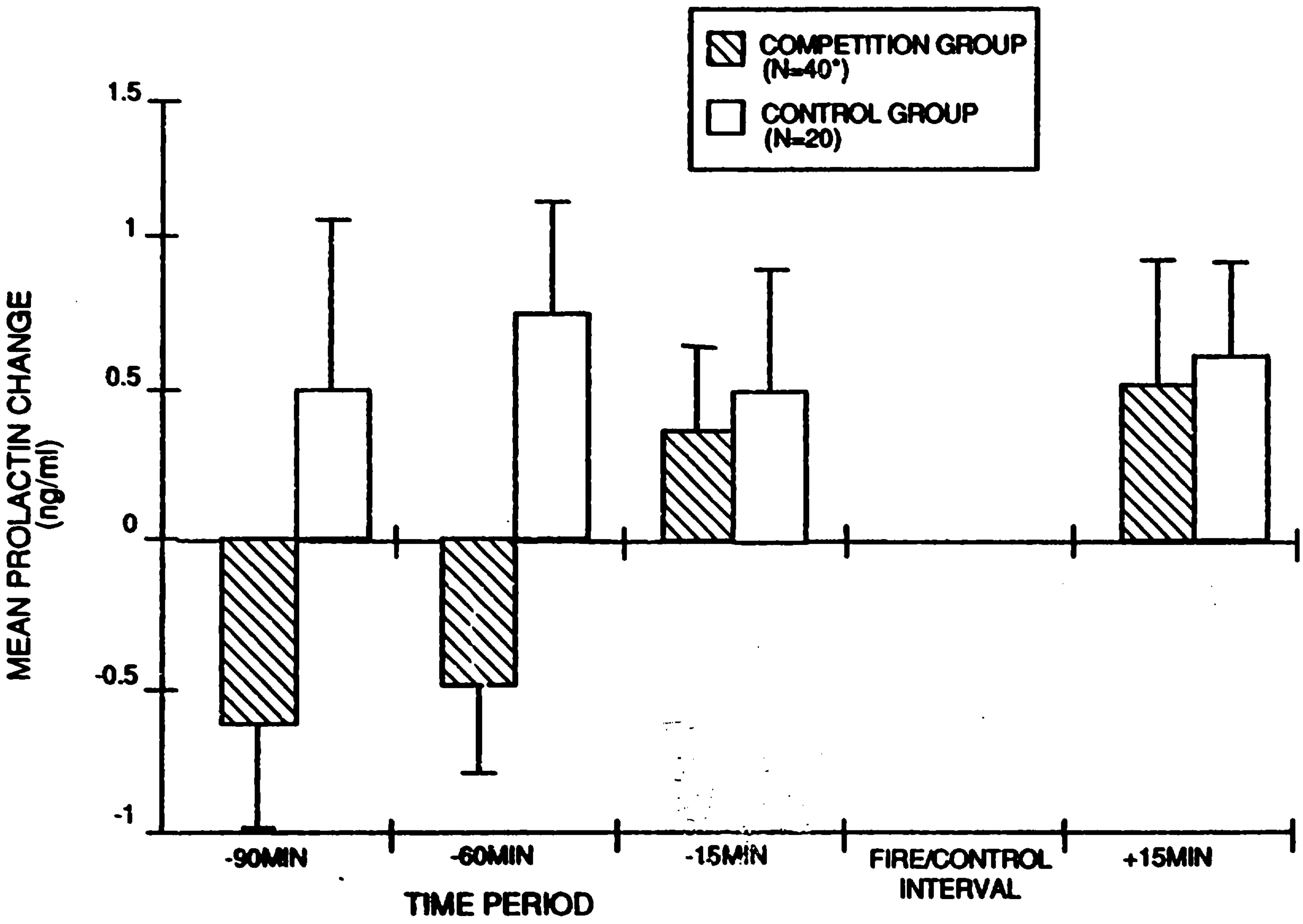


Figure 21. Mean change in levels of prolactin for Competition and Control Groups for the four sampling times common to baseline and record-fire days (Change = record-fire level - baseline level. *N=39 post firing because of catheter failure in one subject.)

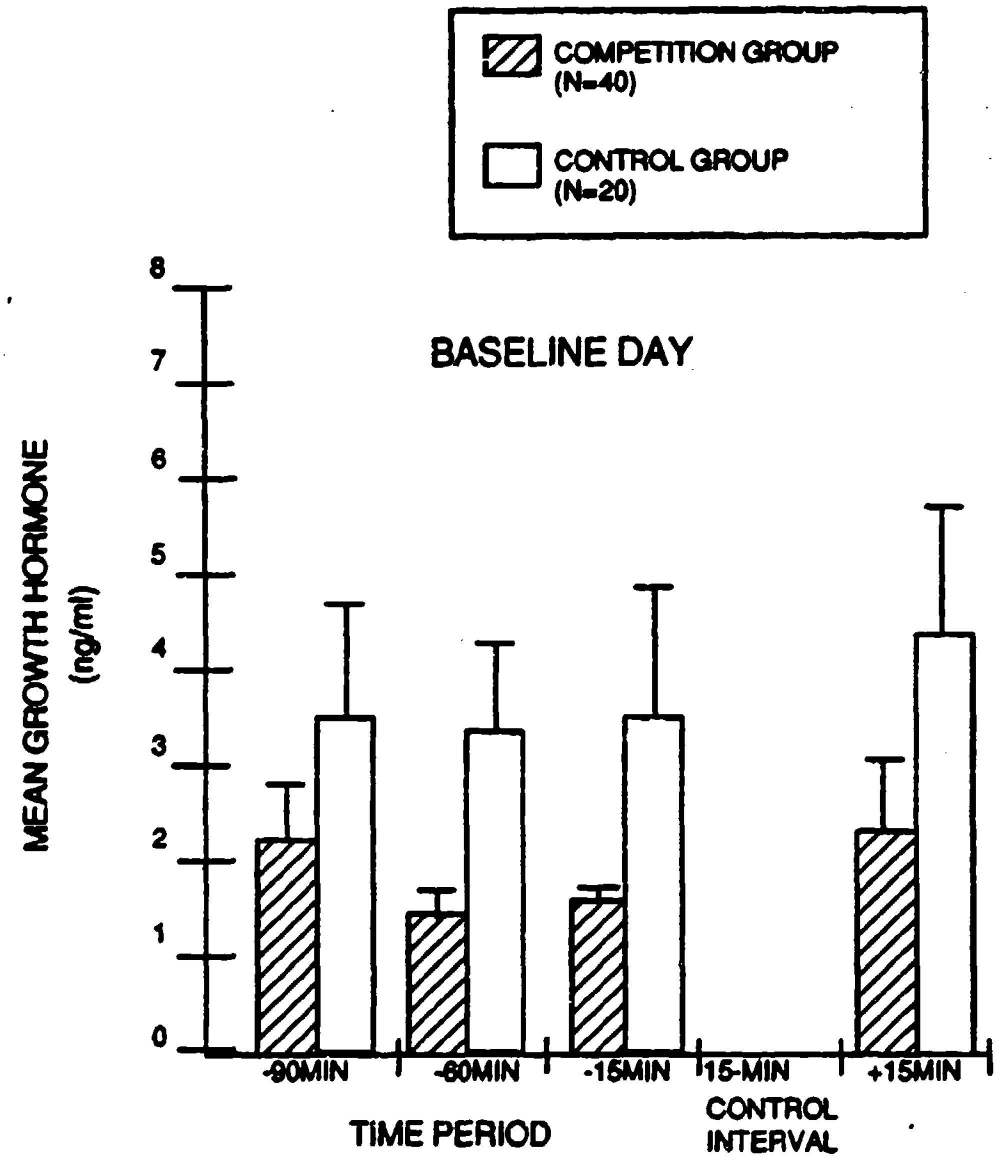


Figure 22. Mean growth hormone levels for Competition and Control Groups at four sampling times on baseline day.

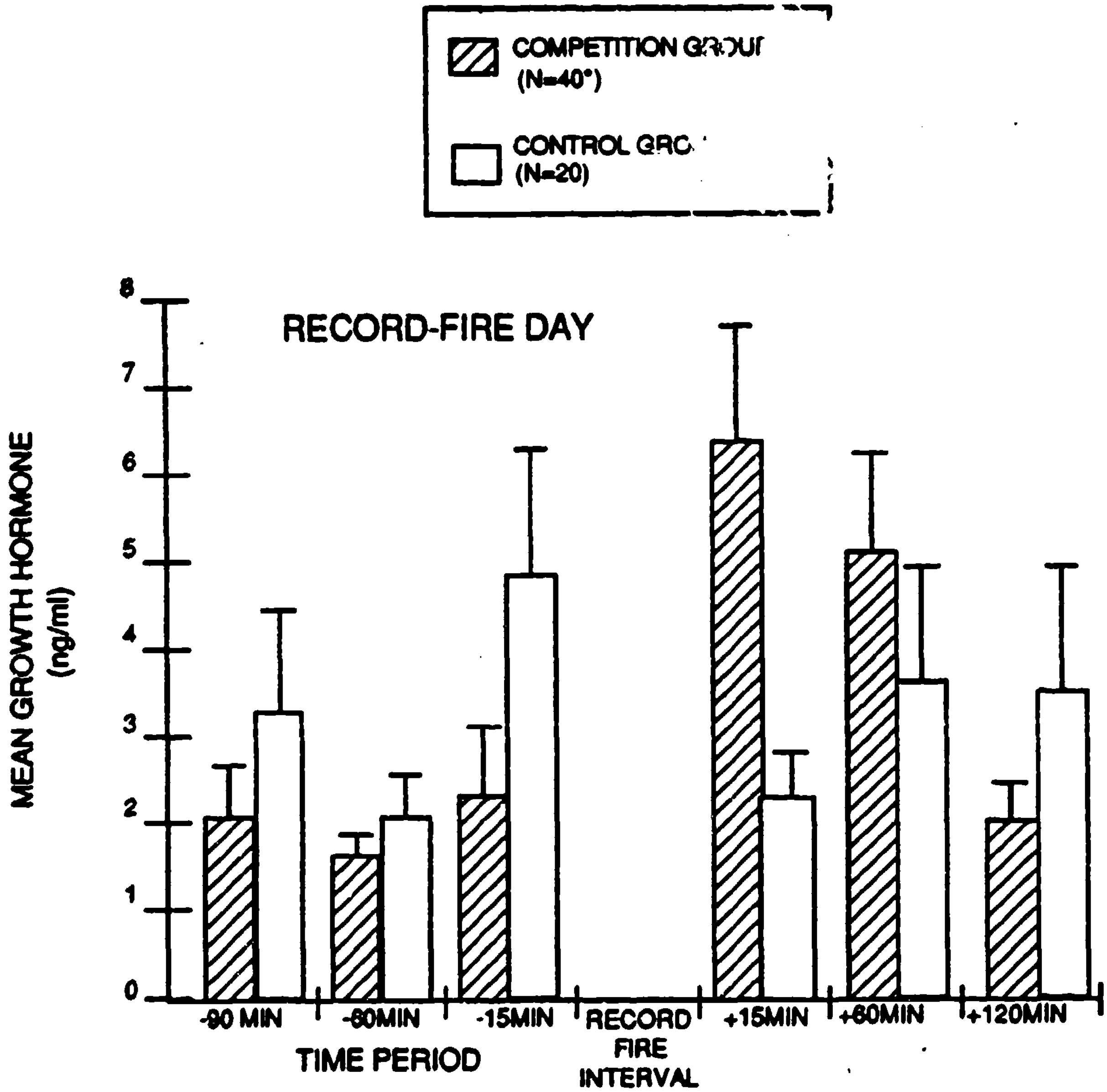


Figure 23. Mean growth hormone levels for Competition and Control Groups at six sampling times on record-fire day (*N=39 post firing because of catheter failure in one subject).

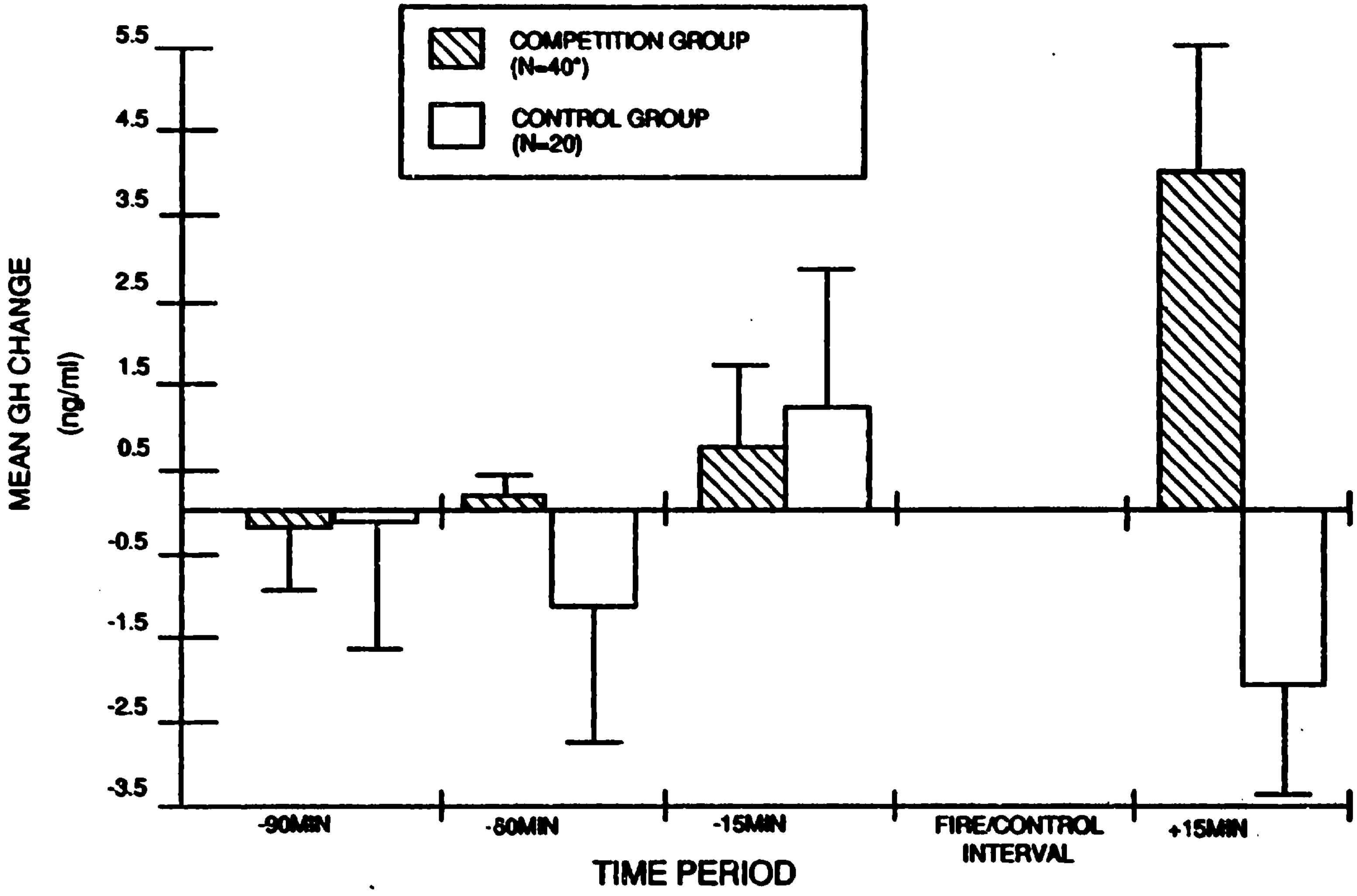


Figure 24. Mean change in levels of growth hormone for Competition and Control Groups for the four sampling times common to baseline and record-fire days (Change = record-fire level - baseline level. *N=39 post firing because of catheter failure in one subject.)

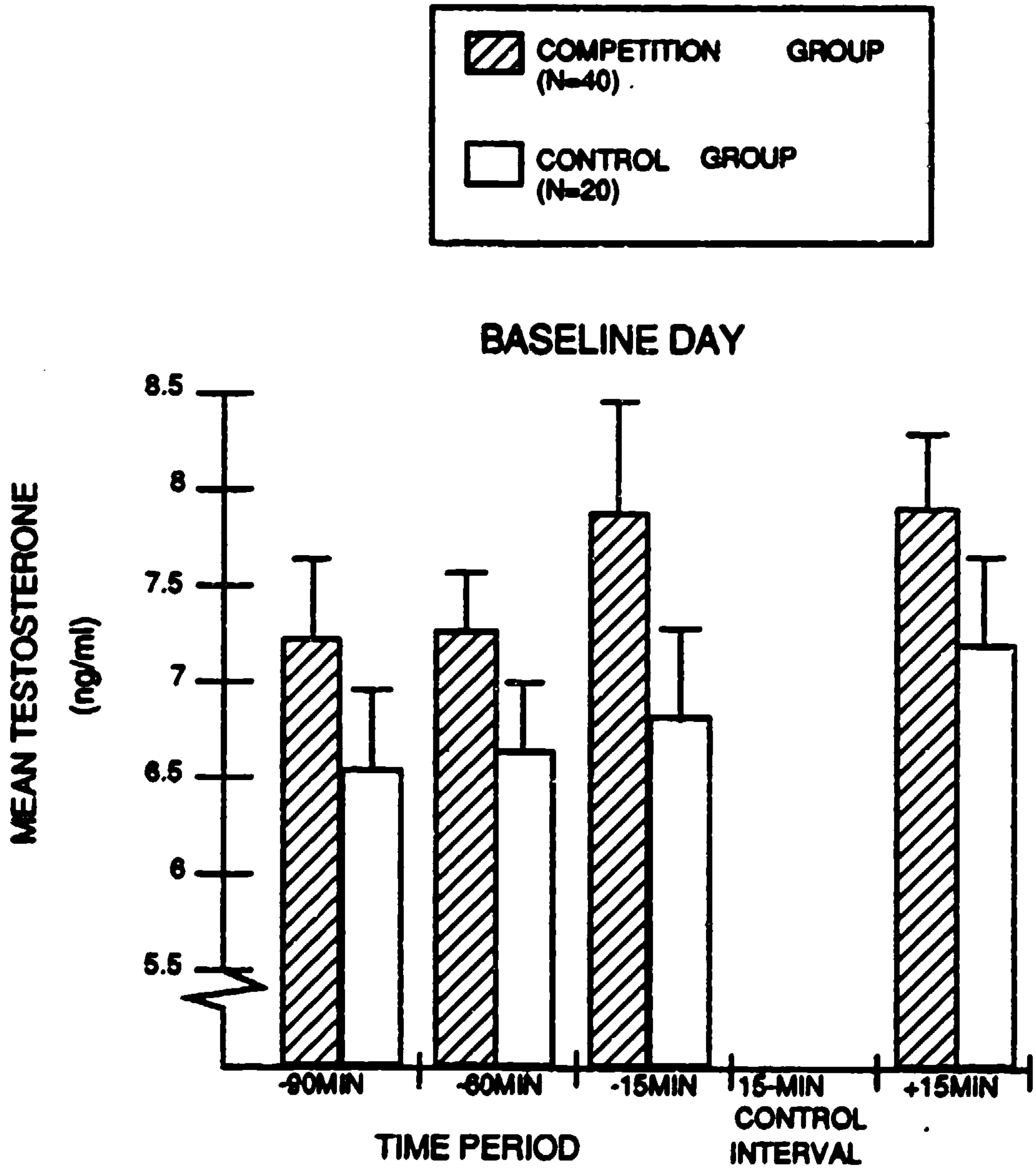


Figure 25. Mean testosterone levels for Competition and Control Groups at four sampling times on baseline day.

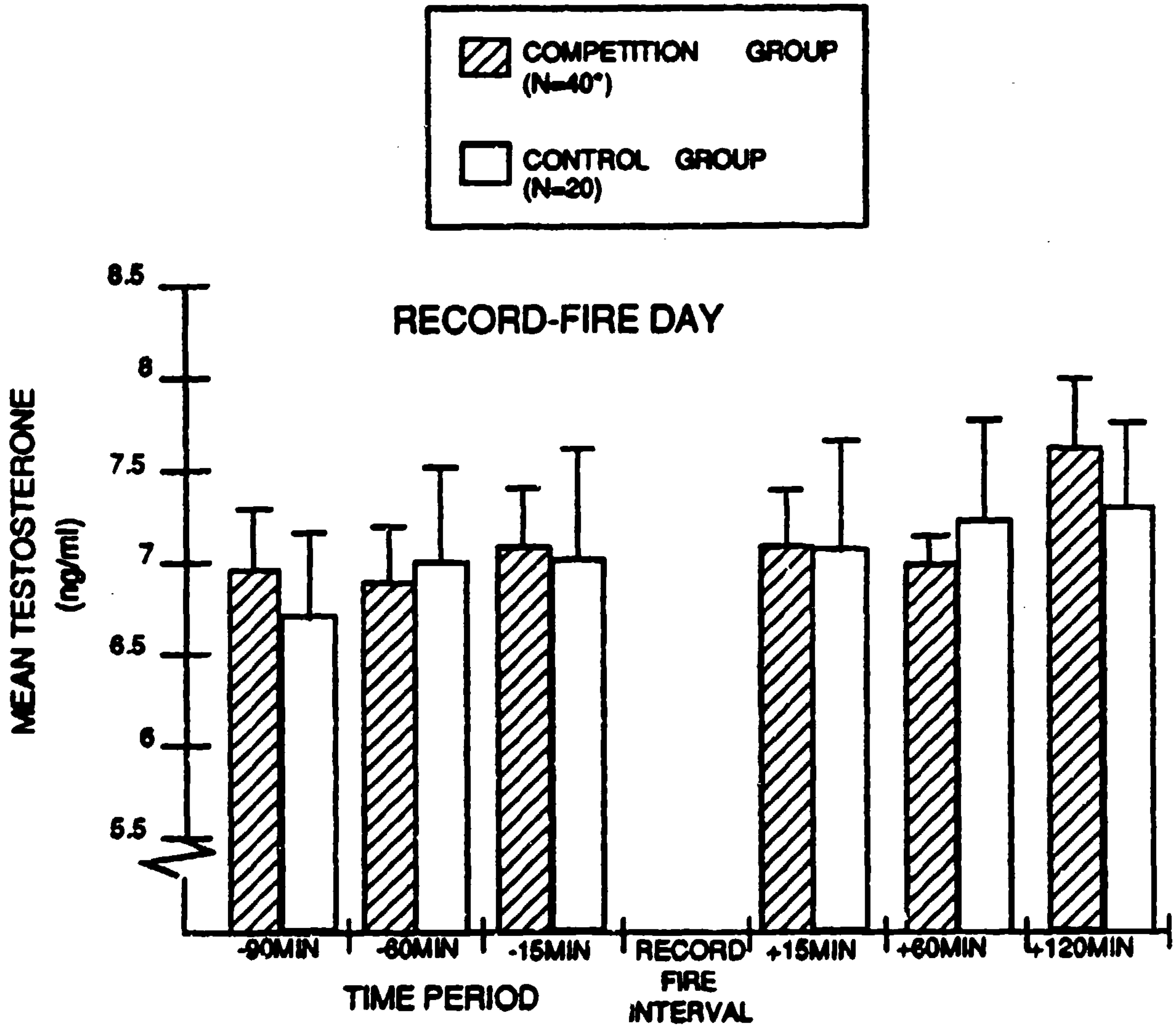


Figure 26. Mean testosterone levels for Competition and Control Groups at six sampling times on record-fire day (*N=39 post firing because of catheter failure in one subject).

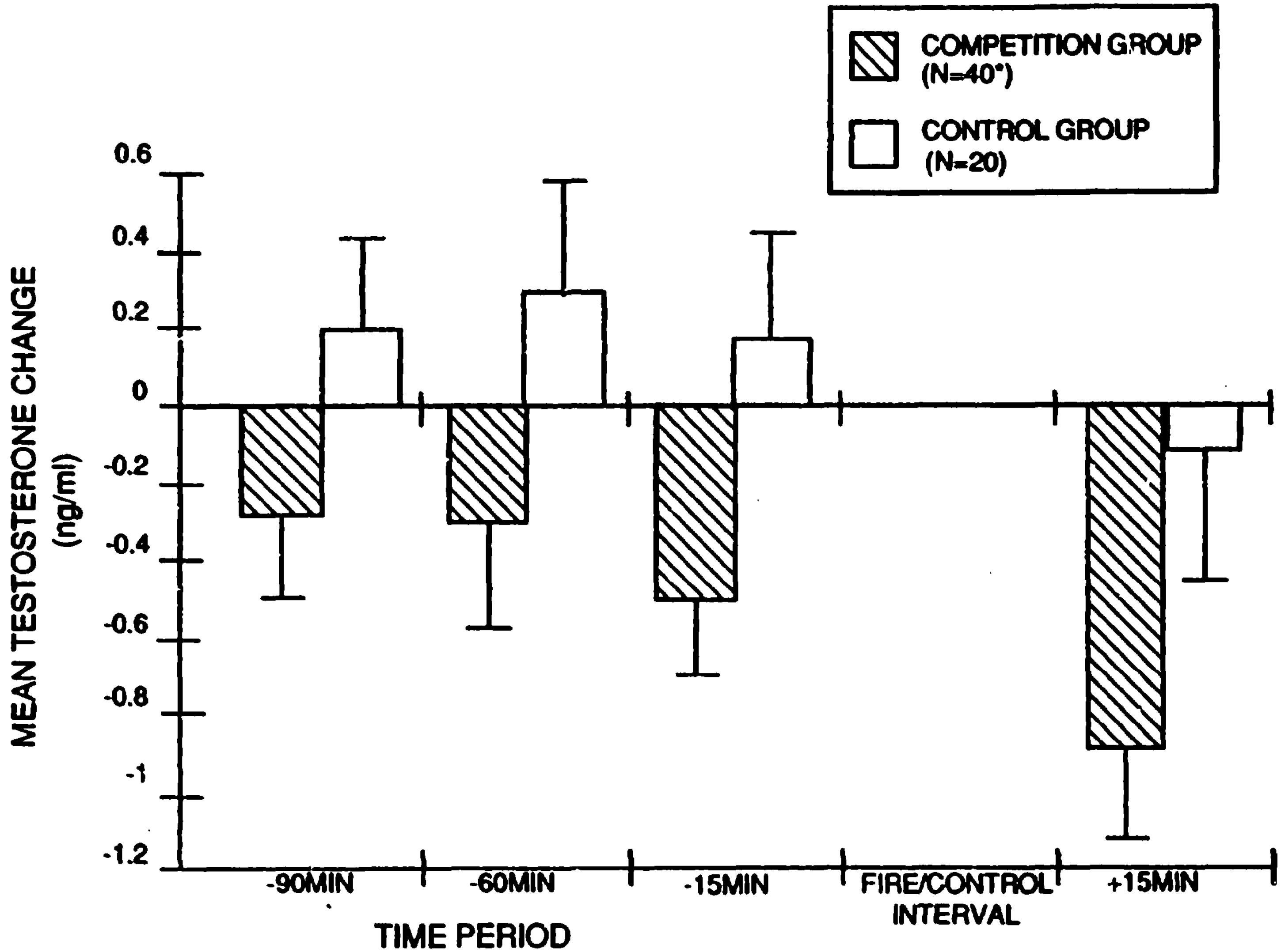


Figure 27. Mean change in levels of testosterone for Competition and Control Groups for the four sampling times common to baseline and record-fire days (Change = record-fire level - baseline level. *N=39 post firing because of catheter failure in one subject.)

Comparative Stress Values for Hormone Responses

In Figures 28 through 32, the SS study mean hormone values (+SEM) for the Competition and Control Groups, at +15 minutes on record-fire day are compared with values obtained by Northwestern University at the same time point for (a) subjects during independent control conditions, (b) medical students taking an important written examination, and (c) men whose wives were undergoing abdominal surgery (under general anesthesia). The +15-minute time point was chosen for comparison because it yielded peak responses for most of the hormones investigated, and it closely coincided with the time post-stress psychological measures were obtained. A MANOVA was conducted for a groups (5) by hormone (5) design. The overall multivariate test was highly significant (Wilks' $\lambda = .520$; $F=4.21$; $df=20,385$; $p<.001$). The results of univariate tests of the groups factor for each hormone are presented below.

Cortisol (see Figure 28)

The group variable univariate test for the cortisol measure ($F=2.25$; $df=4,119$; $p=.07$) was only marginally significant. As shown in Figure 28, the SS Competition Group showed the highest post-stress cortisol of any group included in the research. However, because of the relatively small numbers in many of the groups and the conservative nature of the statistical tests chosen, none of the group differences achieved statistical significance ($CV_{.05}=29.04$).

LH (see Figure 29)

The group variable univariate test for the LH measure ($F=5.78$; $df=4,119$; $p<.001$) was highly significant. Post hoc tests ($CV_{.05}=2.95$; $CV_{.01}=3.55$) indicated that the SS Competition Group and the Written Exam Group displayed highly significant elevated LH ($p<.01$) and the Abdominal Surgery Group showed significantly elevated LH ($p<.05$) as compared with the Independent Control Group, that those three groups did not differ significantly from each other, and that the SS Control Group did not differ significantly from any other group in LH response.

PRL (see Figure 30)

The group variable univariate test for the PRL measure ($F=2.30$; $df=4,119$; $p=.06$) was only marginally significant. Although, as shown in Figure 30, both SS groups displayed lower PRL than any of the Northwestern (stress or control) groups, neither SS group differed significantly from any of the Northwestern groups ($CV_{.05}=1.93$).

T (see Figure 31)

The group variable univariate test for the T measure ($F=4.23$; $df=4,119$; $p=.003$) was highly significant. Post hoc tests ($CV_{.05}=1.5$, $CV_{.01}=1.8$) indicated that both SS groups had T levels significantly higher than that for the Independent Control Group ($p<.01$) and that no other group differences were statistically significant.

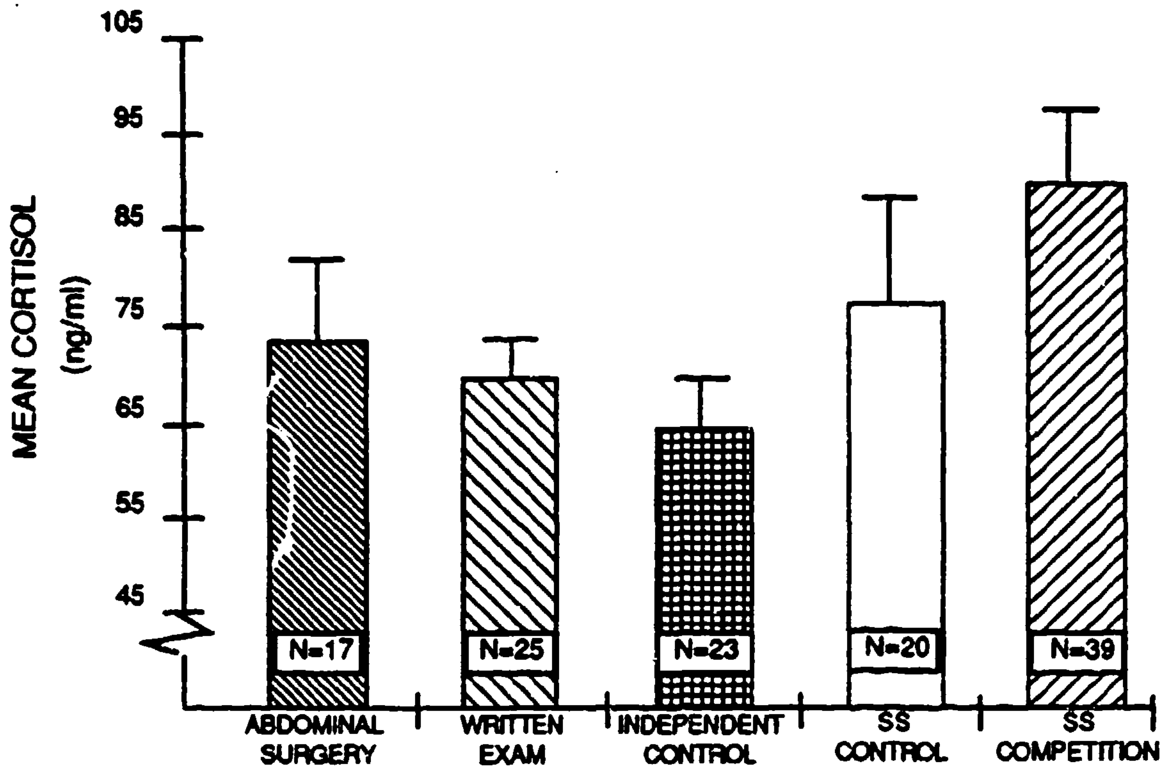


Figure 28. Comparison of 15-minute post-stress cortisol levels for SS Competition and SS Control Groups on record-fire day with those for subjects in the Northwestern University conditions ([1] spouse having serious abdominal surgery; [2] taking an important medical school written exam; or [3] independent non-stress control condition).

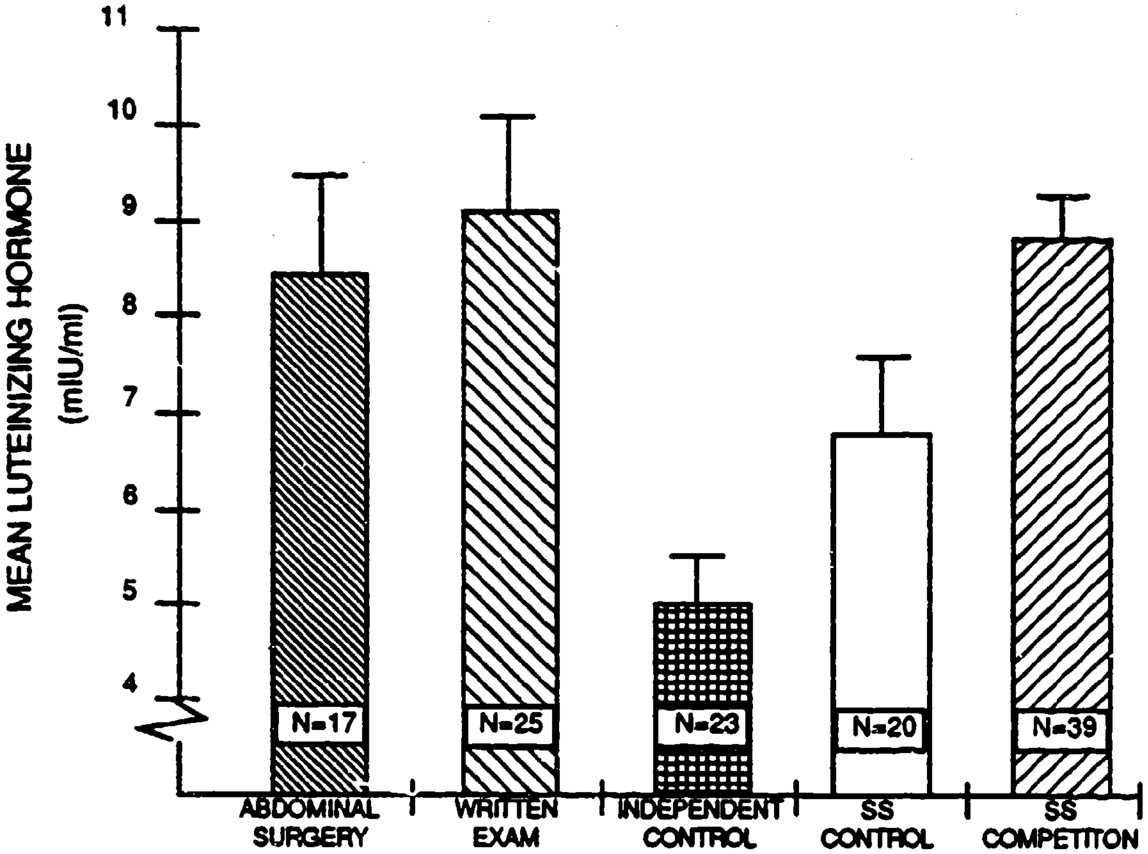


Figure 29. Comparison of 15-minute post-stress luteinizing hormone levels for SS Competition and SS Control Groups on record-fire day with those for subjects in the Northwestern University conditions ([1] spouse having serious abdominal surgery; [2] taking an important medical school written exam; or [3] independent non-stress control condition).

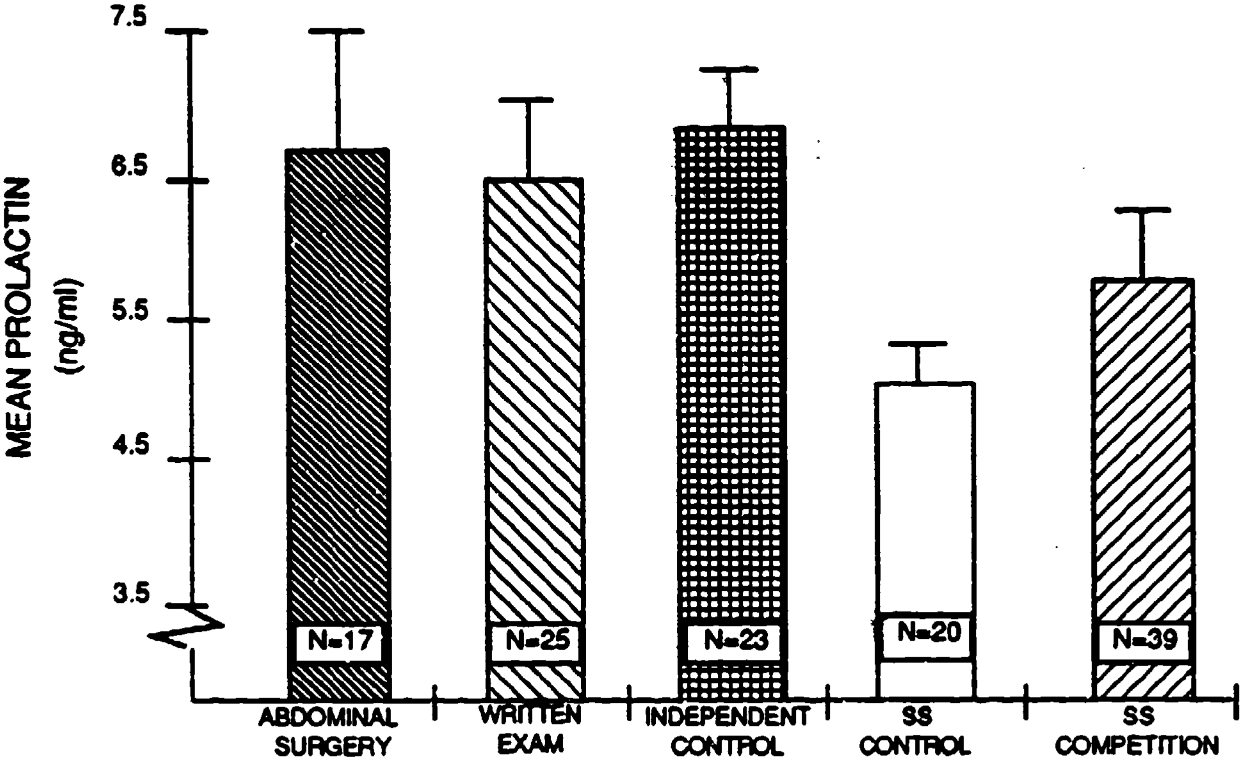


Figure 30. Comparison of 15-minute post-stress prolactin levels for SS Competition and SS Control Groups on record-fire day with those for subjects in the Northwestern University conditions ([1] spouse having serious abdominal surgery; [2] taking an important medical school writter exam; or [3] independent non-stress control condition).

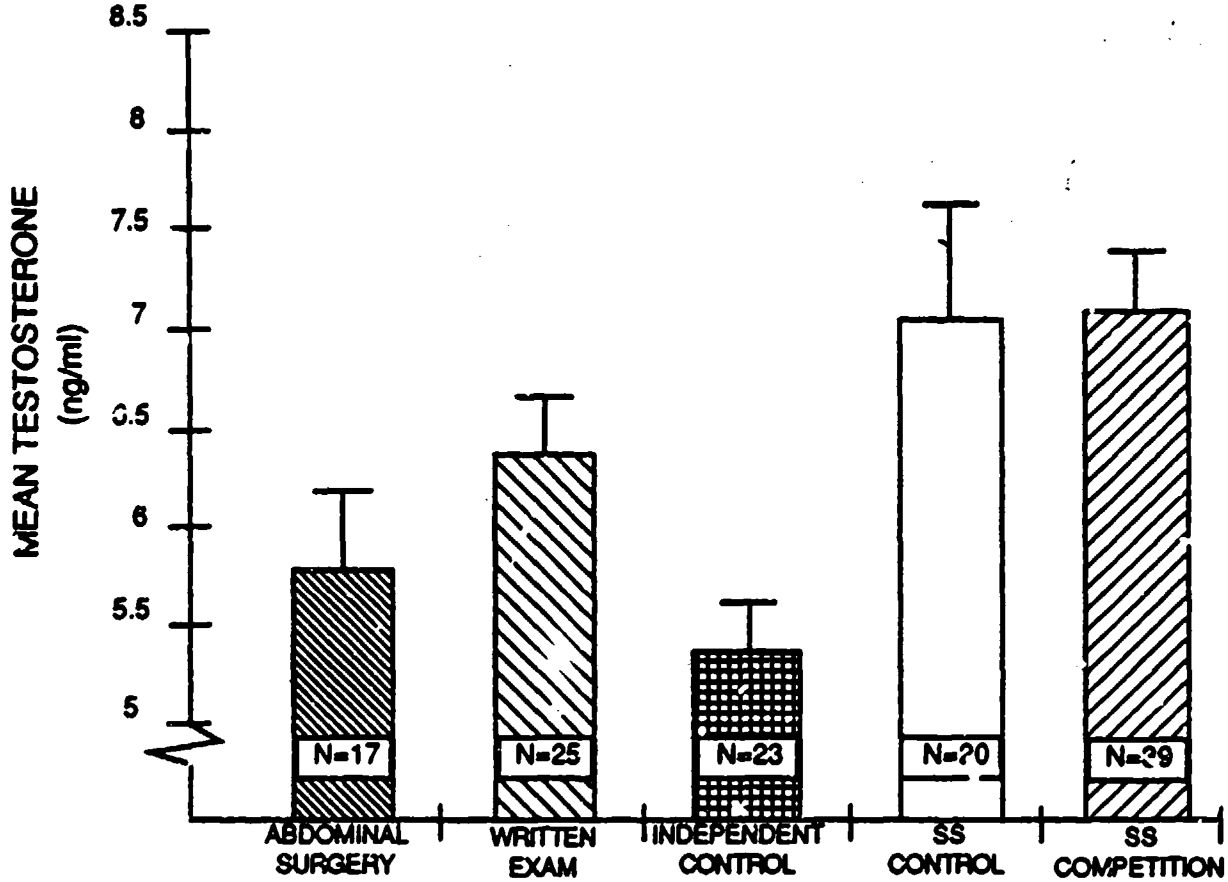


Figure 31. Comparison of 15-minute post-stress testosterone levels for SS Competition and SS Control Groups on record-fire day with those for subjects in the Northwestern University conditions ([1] spouse having serious abdominal surgery; [2] taking an important medical school written exam; or [3] independent non-stress control condition).

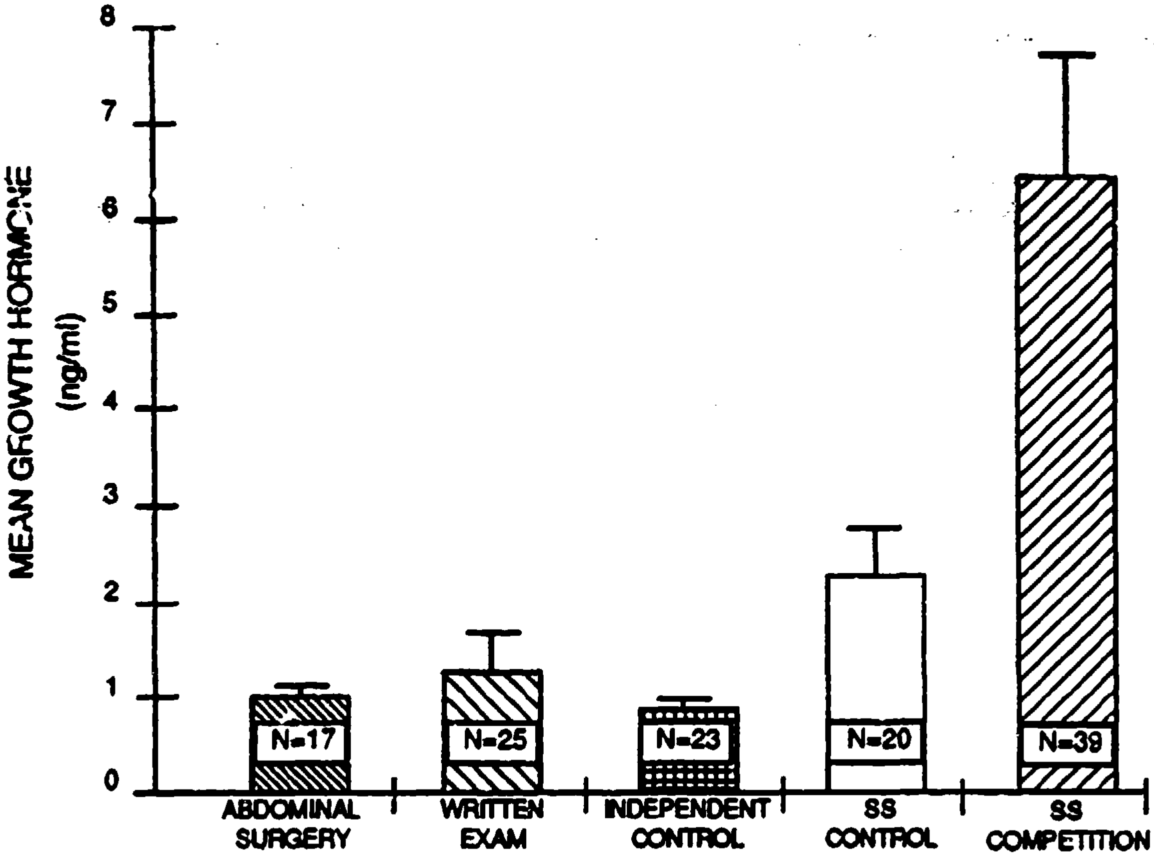


Figure 32. Comparison of 15-minute post-stress growth hormone levels for SS Competition and SS Control Groups on record-fire day with those for subjects in the Northwestern University conditions ([1] spouse having serious abdominal surgery; [2] taking an important medical school written exam; or [3] independent non-stress control condition).

GH (see Figure 32)

The group variable univariate test for the GH measure ($F=7.92$; $df=4,119$; $p<.001$) was highly significant. Post hoc tests ($CV_{.05}=3.87$, $CV_{.01}=4.65$) indicated that the SS Competition Group displayed a GH response level which was significantly greater than that for any of the Northwestern groups ($p<.01$) and the SS Control Group ($p<.05$). No other group differences were significant.

Performance and Hormone Responses

Separate Pearson's correlation matrices were computed for the Competition and Control Groups. Correlations were obtained between record-fire day performance scores (the number of targets hit in the semiautomatic mode [SM] and burst mode [BM] and the total number of targets hit in both modes) and the various hormone values for all 10 time points during the baseline and record-fire days. The significant relationships obtained between performance and hormone levels during the 2 days are summarized in Table 2. Correlations between the performance scores and the changes in hormone response levels from baseline to record-fire day were also computed; significant correlations obtained are summarized in Table 3.

A total of 360 correlations was computed, and 20 were significant at the $p<.05$ level of confidence--only two more than expected by chance. The correlations that achieved statistical significance, however, tended to cluster about a few variables, a fact that gives those correlations more weight than if they had been more randomly distributed. The following limited description of those clustered correlations was therefore deemed appropriate.

For the control condition, better performance in the semiautomatic mode was associated with lower early morning PRL levels on baseline day and with larger early morning increases in PRL from baseline to record-fire day. Better performance for this group was also associated with increased T from baseline to record-fire day. This was most pronounced for performance in the burst mode +15 minutes after firing.

For the competition condition, performance appears to have been most closely associated with levels of T. Semiautomatic mode performance was associated with decreased T from baseline to record-fire day. Better performance in the burst mode, however, was associated with lower T during both days, except near the time of firing on record-fire day. At +15 minutes on record-fire day, better performance was associated with an increase in T from baseline levels. This latter association is the only one that held for both the Competition and Control Groups.

DISCUSSION AND CONCLUSIONS

Within the context of this investigation, hormone data were collected to assist in determining whether the firing competition was stressful to the competing soldiers, and if so, to provide a means of determining the extent of the competition stress.

Each of the hormone measures chosen has been shown by other investigators to be responsive to at least some kinds of stress. The results, described above and discussed below by hormone, generally indicated greater

Table 2

Significant Correlations Between Hormone Levels and Record-Fire Performance Scores

Day	Blood sampling time	Group: Control	(N=20) (df=18)	Competition	(N=40) (df=38)
Baseline					
	-90 minutes	PRL/SM $r=-.48$*	PRL/TOT $r=-.52$*		
	-60 minutes	PRL/SM $r=-.53$*	PRL/TOT $r=-.52$*	T/BM $r=-.39$*	
	-15 minutes			T/BM $r=-.34$*	
	+15 minutes			T/BM $r=-.37$*	
Record Fire					
	-90 minutes			T/BM $r=-.34$*	T/TOT $r=-.31$*
	-60 minutes				
	-15 minutes				
	+15 minutes				
	+60 minutes			T/BM $r=-.32$*	
	+120 minutes				

* $p<.05$
SM - Targets hit in semiautomatic mode
PRL - Prolactin
BM - Targets hit in burst mode
T - Testosterone
TOT - Total targets hit

Table 3

Significant Correlations Between Performance Scores and Change in Hormone Levels from Baseline to Record-Fire Day

Blood sampling time	Control (N=20) (df=18)			Competition (N=40) (df=38)	
-90 minutes	LH/SM $r=+.55$*	PRL/SM $r=+.45$*	GH/SM $r=+.46$*	T/SM $r=-.38$*	
-60 minutes	T/TOT $r=+.47$*	PRL/SM $r=+.52$*			
-15 minutes					
+15 minutes	T/BM $r=+.55$*	T/TOT $r=+.45$*		T/BM $r=+.39$*	GH/BM $r=-.36$*

* $p<0.05$

SM - Targets hit in semiautomatic mode
PRL - Prolactin
BM - Targets hit in burst mode
T - Testosterone
TOT - Total targets hit
GH - Growth hormone
LH - Luteinizing hormone

hormonal stress responses to the test condition for soldiers experiencing competition than for soldiers who experienced control conditions.

Cortisol

Since Selye (1936) first introduced the stress concept, the hypothalamo-pituitary-adrenal axis has been implicated in the stress response, and hormonal measures indicating activation of the axis have served as primary stress indices. In man, the adrenocortical hormone of choice has been cortisol, and generally, elevations in serum cortisol have been considered to indicate stress responses (Baseer & Rab, 1975; Chernow, Alexander, Smallridge, Thompson, Cook, Beardsley, Fink, Lake, & Fletcher, 1987; Levine, 1978; Rubin, Miller, Arthur, & Clark, 1970).

That the competition was stressful is illustrated by the highly significant elevation in cortisol for the Competition Group 15 minutes after record firing. The Control Group (noncompetition) showed a similar but non-significant elevation in cortisol in reaction to firing. When group cortisol data were considered with regard to change from baseline to record-fire day, the only significant change was a highly significant increase at +15 minutes for the Competition Group.

In the absence of any established procedure for determining the level of stress experienced in any given situation, the HEL SS study data obtained for hormonal and psychological measures were compared with data for the same measures obtained by the same procedures in a variety of protocols conducted by Northwestern University. Since the +15-minute time point yielded peak responses for most of the hormones investigated in the SS study, that time point was chosen to compare stress and control values across studies. SS Competition and Control Groups' cortisol values for record-fire day did not differ significantly from those obtained for any group of stressed or control subjects by Northwestern. Thus, the +15-minute cortisol measure does not appear to be particularly sensitive to the different ("stress") treatments compared.

Luteinizing Hormone (LH)

Relatively little has been published about the effects of acute stress on LH levels in humans. Based on recent animal and human studies, acute stressors usually elicit transient elevations of LH, whereas chronic stressors result in below-baseline levels (Briski & Sylvester, 1987; Hayashi & Moberg, 1987; Herbert, Moore, & de la Riva, 1986; Johansson, Laasko, Peder, & Karonen, 1988; Sowers, Raj, Hershman, Carlson, & McCallum, 1977).

The consistently significantly higher LH level of the Competition Group compared to Controls during all 10 time points is not easily interpreted relative to the available literature. No baseline was established at a time more independent of or distant from the events surrounding competition. It is not possible, therefore, to determine if the difference represents a baseline difference between the groups because of some selection factor or some prolonged effect in response to the competition experience extending from anticipation on or before baseline day through recovery on record-fire day. Comparison of the +15-minute time point results with those obtained by Northwestern, however, indicates that the SS Control Group did not differ significantly from the Northwestern Controls, while the SS Competition Group had an LH level highly significantly above that for the Northwestern Controls, like the levels for the two Northwestern stress groups.

Prolactin (PRL)

The preponderance of evidence regarding the effect of acute stressors on prolactin response indicates that the usual effect is one of enhanced secretion (Delahunt & Mellsop, 1987; Mills & Chir, 1985; Seggie & Brown, 1982).

On record-fire day, the Competition Group showed a clear significant elevation in PRL from -15 minutes to +15 minutes associated with firing during competition (PRL dropped significantly to basal level by +60 minutes), while the Control Group showed only an insignificant elevation during the same time period.

With regard to the early morning PRL declines, it is noteworthy that Sassin, Franty, Wertzman, & Kapen (1972) reported a dramatic association between sleep and PRL levels. PRL levels were found to rise several fold beginning shortly after the onset of sleep, fluctuated between 2.5 and 4.5 times basal level throughout the sleep period and then dropped back to basal level within 2.5 hours after awakening. The <u>lack</u> of any decline in PRL in the morning of record-fire day for the Competition Group could be attributable to spontaneous early awakening by members of this group in anticipation of the competition.

While the Competition Group showed a clear PRL response to firing during competition relative to its own baseline and relative to Control Group levels, comparison of +15-minute PRL levels for the present study with Northwestern values did not reflect a stress response. The highest PRL levels obtained in the present study were no higher than those for the Northwestern Independent Control Group at that time point.

Growth Hormone (GH)

While GH is often used in stress studies, particularly when physical stress is involved, the literature about this hormone suggests that changes in blood levels of GH are not elicited as reliably in response to psychological stress as are changes for the other hormones considered in this investigation. As with the other hormones, however, the generally obtained direction of response to acute psychological stress has been an increase (Brown & Heninger, 1976; Delahunt & Mellsop, 1987; Kosten, Jacobs, Mason, Wahby, & Atkins, 1984; Rose & Hurst, 1975; Weitzman & Ursin, 1978).

In the present study, the most relevant finding was the significant increase in GH shown by the Competition Group from 15 minutes before to 15 minutes after firing for record. The Control Group remained quite stable over all time points for baseline and record-fire days. At times other than 15 minutes and 60 minutes after record fire, the Competition Group displayed GH levels which were consistently lower than those for the Control Group. Since there is no reason to suspect any difference in the physical activity of the two groups in this study, the authors can offer no explanation for this group difference.

Comparison of the present GH results with those obtained by Northwestern suggests that the Competition Group was significantly more responsive than any of the other groups that did not differ significantly from each other. This overall difference might be partially attributed to differences in physical activity associated with blood collection (Chatterton, DeLeon-Jones, Hudgens, Dan, & Cheesman, 1985). In the present study, the subjects had to walk about 30 yards and climb a short flight of steps between their waiting area and the blood collection point, whereas the Northwestern subjects were relatively inactive. Hartley, Mason, Hogan, Jones, Kotchen, Moughey, Wherry, Pennington, & Ricketts (1972) have shown that physically well-trained (fit) subjects, as these subjects were, exhibit increasing levels of GH from rest, to mild, to moderate levels of exercise. As noted above, however, this explanation does not account for the highly significant difference in GH for the two SS groups.

Testosterone (T)

While some investigators have recently reported that T is unaffected by the stress of a major examination (Herbert et al., 1986; Johansson et al., 1988), Cumming and Rebar (1985) found that T is increased by anticipation of acute exercise. Furthermore, Delahunt and Mellsop (1987) reported that T has been found to decrease in response to several moderate and enduring or chronic stressors such as major surgery, illness, and exercise. Davidson, Smith, and Levine (1978) also found that T was suppressed shortly after an initial jump in parachute trainees. However, they also found T levels to be enhanced 20 minutes after several subsequent jumps. They noted that the T response to acute psychological stress had not been elucidated for humans. This still appears to be the case.

Because the present investigation involved soldiers (trained fighters) firing potentially lethal weapons during competitive conditions, it was anticipated that aggressive tendencies might be reflected more in this situation than in other stress protocols like those conducted by Northwestern. Furthermore, other investigators have reported associations between T and aggression. Persky, Smith, and Basu (1971) reported a significant positive correlation between the production of T and expressions of aggression on a hostility inventory by healthy young men. Two groups of investigators (Ehrenkrantz, Bliss, & Sheard, 1974; Kreutz & Rose, 1972) have reported significantly higher T levels in prisoners with histories of chronic violence as compared with prisoners without such histories.

The T levels obtained for both groups in the present investigation were higher than in any protocol conducted by Northwestern to date. This supported the authors' expectancy for the soldier subjects. Support also was provided for the hypothesis that T levels in the SS Competition subjects were related to a tendency to be aggressive; SS Control Group hostility scores after firing were as high as any obtained by Northwestern and were significantly higher for the SS Competition Group. Those findings are presented and discussed in more detail in Chapter 4. It is unlikely that the high T levels for the soldiers in this study, relative to the subjects in the Northwestern protocols, can be accounted for by an age difference. Vermeulen, Rubens, and Verdonck (1972) reported that the mean range of plasma testosterone levels remains constant from adolescence to age 50, drops only moderately during the sixth decade, and drops progressively more rapidly through the seventh, eighth, and ninth decades. Although the mean age of the soldiers (21.9 years) is a little younger than for subjects in the Northwestern protocols, the mean ages for all groups cited is well within the 20- to 50-year range where T remains stable.

Superimposed on these relatively high levels of T in the Competition Group was a significant suppression of T around the time of record firing relative to baseline day values. This suppression was not exhibited by the Control Group.

The consistently high levels of T obtained for the subjects in this study have been interpreted as reflecting the generally high level of aggression in these subjects relative to the Northwestern subjects. These high levels could be interpreted alternatively as reflecting high anxiety, presumably anxiety about firing for record, in line with findings reported by Cumming and Rebar (1985). While quite possible, this interpretation seems less plausible because the two groups responded so similarly. It is the suppression of T shown by the Competition Group, and not the Control Group, on record-fire day that seems more likely to reflect a stress response like that reported by Davidson et al. (1978).

Performance and Hormone Responses

In addition to providing information about the presence or absence of stress and the degree of stress experienced, the physiological and psychological data obtained in this study provide information about which measures might show relationships to performance. The study suggests that PRL, and particularly T, might relate to rifle-firing performance. During relatively noncompetitive conditions (Control Group), rifle-firing performance for the semiautomatic mode was significantly related to early morning PRL levels obtained the day before record firing. This same performance was related to the change in early morning PRL levels from baseline to record-fire day. Better semiautomatic mode performance was thus related to lower PRL levels on baseline day and by greater increases in PRL from baseline to record-fire day for soldiers firing during conditions normal for weapons qualification, familiarization, and testing. Their burst mode performance, however, related best to increased T from baseline to record-fire day.

Performance during the competitive conditions of this study (Competition Group) was most related to levels of T. Better performance within the Competition Group in the burst mode was related to relatively lower levels of T on baseline day at all time points and on record-fire day at times remote to the time of firing. Near the time of firing, burst mode performance related best to increased T from baseline to record-fire day. Better performance for this group in the semiautomatic mode was related to a relatively greater decrease in T from baseline to record-fire day at -90 minutes. While a relationship between T and firing in competition was anticipated, no explanation is apparent for the relationship being limited to performance in the burst mode. Also, there is no ready explanation for why PRL was related to performance for the Control Group and not the Competition Group. Further study will be required to determine the reliability of these relationships between hormone levels and performance.

Competition as a Stressor

One of the primary purposes in conducting this study was to make a preliminary evaluation of competition as a stressor. If the competition generated in this study proved stressful, it would indicate that competition might be an important component in developing procedures for testing human-machine systems during stressful (and therefore more realistic) conditions.

The hormone findings within this study provide good evidence that subjects in the competitive condition were more stressed than subjects in the control condition. On record-fire day, cortisol was significantly elevated 15 minutes after firing, relative to prefiring levels, for the Competition Group but not the Control Group. LH was elevated during all time points for the Competition Group relative to the Control Group. This was interpreted as possibly reflecting greater generalized anxiety for the group expecting to fire for record during competitive conditions. This interpretation is generally in line with the findings reported in Chapter 4 for the anxiety measures. The Competition Group showed significant increases in PRL and GH 15 minutes after firing, relative to prefiring levels, while the Control Group did not. And for the T measure, the Competition Group exhibited a suppression of T for record-fire day relative to baseline day, and the Control Group did not. While the literature at this time is not always clear about what should be expected in the way of a "stress response" for a given hormonal measure in all situations, it is clear from our findings that the SS groups differed in their responses within the study. Furthermore, the differences obtained can be, and have been, related to predominant stress response patterns reported in the literature.

Further evidence that the competition condition in the SS Study resulted in increased stress response beyond that of the control condition was provided by the comparisons of hormone levels 15 minutes after firing for record for both groups with hormone levels similarly obtained for stress and control conditions at Northwestern University. While no statistically significant group differences were obtained, the cortisol level obtained for the SS

Competition Group was the highest obtained for any of the groups compared. The SS Competition Group LH level was significantly higher than the Northwestern control level, as were the levels for the Northwestern stress groups, while the SS Control Group level did not differ significantly from Northwestern control level. The SS Competition Group GH was significantly elevated in comparison to all other groups. While this latter finding for GH suggests that competition might generate a high stress level, the findings for the other hormones suggests a more moderate stress level, in the range of that found for the Written Exam Group.

In this study, as in virtually all studies reported in the literature, not all subjects exposed to the experimental stress condition appear to have been stressed. Individuals' thresholds for stress vary. Most stressful situations do not stress everyone. This is most likely to be the case for low and moderate intensities of stress. As the stress intensity is increased, however, the threshold for stress will be reached for a greater percentage of individuals (Levine, Weinberg, & Ursin, 1978).

This study demonstrated that competition can be used during conditions like those used in this study to stress groups of subjects. It is not clear, however, whether competition can be manipulated within current human use guidelines to achieve even higher levels of stress. And, in the evaluation of human-machine weapon systems during stress, it seems reasonable that the stress used should be of high intensity, which would be expected in combat situations. It is during such high intensity stress conditions that the human-machine system's performance is most likely to be adversely affected.

Since no good alternative presently exists as a means of stressing subjects in systems evaluation, and since competition as created in this study has now been shown to be at least moderately effective in this regard, it appears that some effort should be directed toward determining what steps are necessary to make competition a more effective stressor. The importance of testing systems during stressful conditions may require testing subjects during other than minimal risk conditions.

While there is no indication that hormone or other physiological measures will be necessary elements of any eventual standing operating procedure (SOP) involving competitive stress, these measures have been critical to the evaluation of competition as a stressor. The continued development and refinement of stress metric indices, both physiological and psychological, will be critical to the achievement of a reliable method for stressing subjects and systems to a level that models combat stress conditions.

CHAPTER 4

PSYCHOLOGICAL RESPONSES TO COMPETITIVE MARKSMANSHIP

(L. T. Fatkin, G. A. Hudgens, J. P. Torre, Jr., J. M. King, R. T. Chatterton, Jr.)

INTRODUCTION

The evaluation of psychological and physiological responses of soldiers performing combat-relevant tasks during stressful conditions is a critical step toward accounting for the human factor in battle outcomes. The psychological data presented here were obtained as components of the competitive stress evaluation program and projected Advanced Combat Rifle (ACR) field evaluation discussed in previous chapters.

Projected fundamental contributions of this program include the development of standard procedures for soldier-equipment performance testing, as well as a determination of which combination of psychological and physiological indices would provide efficient and reliable measurements of the stress experienced. In the present study, these indices will be used to determine (a) whether the soldiers involved in competitive marksmanship exhibited typical stress responses; (b) the level and intensity of their stress experience; and (c) how the level of stress related to their marksmanship performance.

The predominant view of what constitutes the experience of stress is a multifaceted, dynamic, and interactive process with psychological and physiological dimensions. The interactive model of stress used within the HEL Stress Research Program includes the following dimensions:

STRESS VARIABLES	x	INDIVIDUAL VARIABLES	=	UNIQUE STRESS RESPONSE PROFILE
KIND		PERSONALITY		PHYSIOLOGICAL VARIABLES
INTENSITY		EXPERIENCE		PSYCHOLOGICAL VARIABLES
				TIME VARIABLE

The type and intensity of the stressor, as well as a variety of individual variables (e.g., personality, perceptions, experience, or outcome expectations) are examined. These variables may result in unique physiological and psychological response profiles within the anticipation and recovery phases.

Lazarus (1966) conceptualized stress within the general context of homeostasis; a state of stress is produced when stressors (environmental or social) tax or exceed an individual's adaptive resources. The stressful state will be characterized by the arousal of various emotions of negative affect (e.g., uncertainty, frustration, irritability, tension, fear, or sadness) as well as a variety of positive affects (e.g., excitement, enthusiasm, curiosity, or adventure). Lazarus emphasized that few general claims can be made regarding psychological responses to stress because individual differences permeate every step of the process of stress arousal and reduction. Hogan and Hogan (1982) observed that although this pervasiveness of individual differences in stress reactions has been noted in literature reviews during the past 3 decades, valid and reliable measures of an individual's stress proneness or vulnerability, perceptions and appraisals of the stressors, expectations, experiences, moods, and coping resources are rarely used within the same study. The present study included measures of the above factors to test the stress generated by unit competition. This chapter evaluates the stressfulness of the situation by using the battery of psychological measures and comparing the levels of stress-related responses reported with those obtained in other protocols conducted as part of the HEL stress program.

METHOD

Subjects

Subjects were described in Chapter 1.

Demographic Information

A general information questionnaire was administered to all subjects 2 days before the weapon firing was scheduled. The questionnaire was used to obtain pertinent demographic and medical information, including age, pay grade, length of service, education level, physical profile status, current use of prescription and non-prescription drugs, current weapons qualifications (number of different weapons), last weapons qualification achieved (sharpshooter, marksman, expert), total rounds fired, and specialized training (sniper school, formal small arms training, etc.).

Psychological Measures and Procedures

Psychological measures were obtained using a battery of standardized questionnaires designed to assess the subjects' perceptions of unit cohesion and morale, amount of current life stress, personality traits, coping strategies, and perceptions of stress. Personality, unit cohesion, and general life stress measures were obtained 2 days before the competitive weapons firing was scheduled, for both the Competition and Control Groups. The stress perception and coping measures were completed by the subjects 10 minutes before and after the firing interval, as indicated in Figure 33. The measures given just before the firing interval assessed how the subjects were feeling "right now," while the post measures instructed them to rate how they felt "during the firing event or control interval." Each of the measures used was designed to be self-administered, relatively brief, and easily given to individuals or groups.

Perceptions of Unit Cohesion and Morale

Two measures of unit perceptions were

1. The Unit Cohesion and Morale Questionnaire (Marlow, Furikawa, Griffith, Ingraham, Kirkland, Martin, Schneider, & Teitelbaum, 1985) required each individual to rate his perception of his unit's level of morale and readiness for combat, and his confidence in his leaders and weapon systems, using a five-point scale.

2. The Squad-Platoon Perceptions Questionnaire (Marlow et al., 1985) asked each individual to indicate (on a 5-point scale) the degree to which he agreed or disagreed with statements concerning squad platoon members and his leaders.

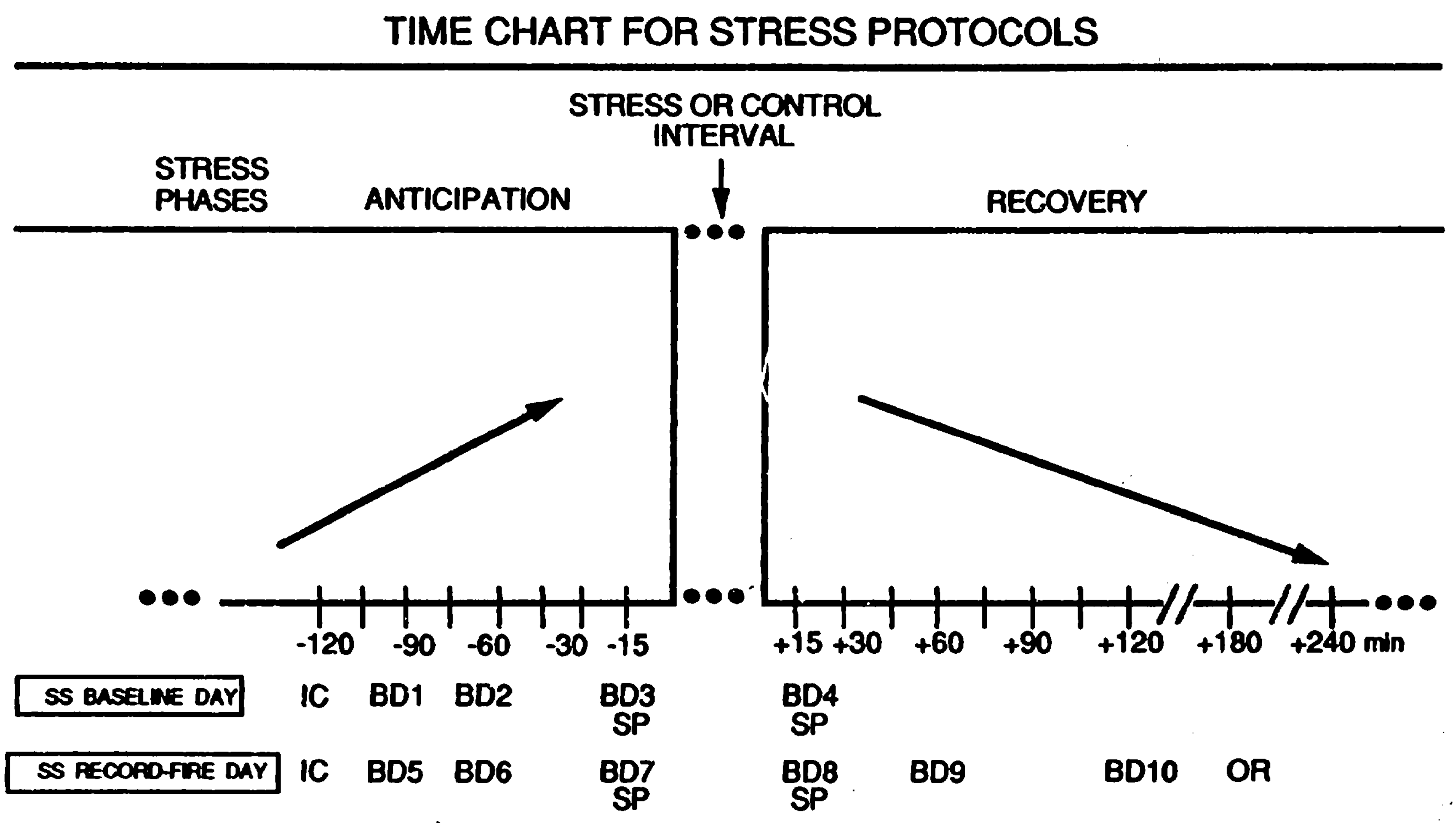


Figure 33. Time chart for stress protocols indicating insertion of catheter (IC), time of blood draws (BD1-BD10), stress perception measures (SP), and overall rating of events (OR).

Amount of Current Life Stress

The Life Events Form I and II (see Appendix E) was used to assess the amount and type of naturally occurring stressors that the subjects may have been experiencing at the time of the study. The Life Events Form I, administered on the same day as the personality measures, asked subjects to rate the amount and type of stress they had "recently" experienced. The Life Events Form II was administered at the start of each test day (baseline day and record-fire day) and asked subjects to rate the amount and type of stress they experienced within "the last 24 hours."

Trait Measures

The following trait measures were used:

1. The State-Trait Anxiety Inventory (STAI) Form Y-2 (Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983) consists of 20 statements that assess how the respondents "generally" feel. The essential qualities evaluated by the STAI were feelings of apprehension, tension, nervousness, and worry.

2. The Multiple Affect Adjective Checklist--Revised (MAACL-R) General or Trait form (Zuckerman & Lubin, 1985) consists of five primary subscales (Anxiety, Depression, Hostility, Positive Affect, and Sensation Seeking) derived from a one-page list of 132 adjectives. An overall distress score, Dysphoria or Negative Affect, was calculated by adding the Anxiety, Depression, and Hostility scores. The respondents were instructed to check all the words that described how they "generally" feel.

Raw scores for each subscale were converted to standardized scores. The standardization sample for the MAACL-R Trait form was the general population stratified sample. To control for small, moderate, or large individual response sets, both the Trait and State forms are standardized within different ranges of total number of items checked.

3. The Sensation Seeking Scale (SSS), Form V (Zuckerman, 1979) contains four subscales (Thrill and Adventure Seeking, Experience Seeking, Disinhibition, and Boredom Susceptibility). Respondents were presented with a 40-item, forced choice questionnaire that was titled, "Interest and Preference Survey." A "Total" score, which was based on the sum of the four subscale scores, was used.

4. Rotter's Internal-External Scale (Rotter, 1966) was used as a measure of locus of control. Respondents were asked to complete 29 forced choice items (including six "filler" statements) relating to their locus of control beliefs. If individuals perceived that an event was the result of luck, chance, fate, or as being controlled by powerful others, it constituted a belief in "external" control. If they perceived that the event was contingent upon their own behavior or their own relatively permanent characteristics, it was a belief in "internal" control.

5. The Eysenck Personality Questionnaire (EPQ) recognizes three distinct dimensions of personality: Extraversion-Introversion (E), Neuroticism (N), and Psychoticism (P) (Eysenck & Eysenck, 1975). When the EPQ-P and EPQ-N scales were used for measuring personality traits in normal persons, Eysenck and Eysenck (1975) described them as measures of "emotionality," "toughmindedness," or "stability-instability."

Coping Measures

Measures of coping included

1. The Revised Ways of Coping Checklist (RWCCL) (Vitaliano, Russo, Carr, Maiuro, & Becker, 1985) identified five individual coping efforts: problem-focused thoughts or behaviors, seeking social support, wishful thinking, blaming self, and avoidance. Raw scores were converted to relative scores to eliminate bias resulting from differences in the number of items on each scale (Vitaliano, Maiuro, Russo, & Becker, 1987).

2. A Coping Efficacy scale asked respondents to rate (from 1 to 10) their level of confidence in their ability to do well. This scale was adapted from a self-efficacy scale developed by Bandura (1977) for investigating the predictive power of efficacy expectations about behavior or performance. Bandura (personal communication, December 31, 1985) suggested that self-efficacy scales be tailored to the testing situation through simple modifications of the instructions.

State Measures

A 5-minute battery of stress perception measures was given immediately before and after the competitive firing on record-fire day and before and after a comparative interval on the previous baseline day. The battery included

1. Form Y-1 (State Form) of the STAI (Spielberger et al., 1983).

2. The Today Form of the MAACL-R (Zuckerman & Lubin, 1985). Because of the improved discriminant validity and the control of the checking response set, the MAACL-R has been particularly suitable for investigations that postulate changes in specific affects in response to stressful situations.

3. The Subjective Stress Scale (SUBJ STRESS) was developed by Kerle and Bialek (1958) to detect significant affective changes in stressful situations. subjects were instructed to select one word from a list of 15 adjectives that best described how they felt.

4. The Specific Rating of Events scale (SRE), was a post-measure designed for this program, in which the subjects rated (on a scale of 0 to 100) how stressful the event was to them. This scale is included in Appendix E.

RESULTS

Salvo Stress Study Group Differences

Demographic Data

Multivariate analyses of variance (MANOVAs) indicated that there were no significant differences between the Control and Competition Groups concerning demographic factors such as age and rank, nor were differences found in variables reflecting type and amount of military experience, such as length of service and current weapons qualifications.

Unit Cohesion and Morale

There were no significant differences in unit perceptions concerning leadership qualities, level of morale, readiness for combat, or level of unit confidence between the 101st and the 82nd Airborne Divisions.

Trait Measures

A MANOVA indicated that there were no significant differences between the Competition Group and the Control Group concerning the trait measures used.

Coping Measures

The coping data were also analyzed using MANOVA, which included the five subscales of the RWCCL (Problem-focused, PFOC; Social Support, SUPP; Wishful Thinking, WISH; Blaming Self, BLAME; and Avoidance, AVOID), and the Coping Efficacy scale. There were no significant differences in these coping measures between the two groups.

State Measures

MANOVAs indicated that there were significant group differences in the state measures only for record-fire day. Subsequent separate MANOVAs were conducted about the variables to test the effects and interactions of groups (Competition and Control) x Measures (nine state measures) x Period (Pre and Post).

A three-way interaction effect for Groups (2) x Measures (9) x Pre/Post Period (2) was significant (Wilks' λ = .678; $F(8,45) = 2.67$, $p = .017$) for record-fire day only. Subsequent MANOVAs were conducted for each state measure, using Groups (2) x Period (2) designs. Post hoc tests conducted of the significant interactions used the Tukey-Kramer modification of the Tukey HSD test which was appropriate for comparisons with unequal numbers of observations (Wilkinson, 1988, p.709). Figures 34 through 40 present mean responses (+standard error of the mean, SEM) for these variables.

STAI Anxiety (see Figure 34)

There was a groups main effect indicating that the Competition Group reported higher Anxiety scores than the Control Group ($F(1,53) = 4.23$, $p = .045$). A Period main effect indicated that the Anxiety scores increased significantly from pre- to post-firing periods ($F(1,53) = 11.13$, $p = .002$).

Subjective Stress Scale (SUBJ STRESS) (see Figure 35)

Although the Groups x Period interaction effect was not significant at $p < .05$ ($F(1,53) = 3.40$, $p = .07$), the pattern of responses for each group is worth noting. As illustrated in Figure 35, while the stress rating for the period during the weapon firing (post measure) increased slightly for the Competition Group, the rating decreased for the Control Group.

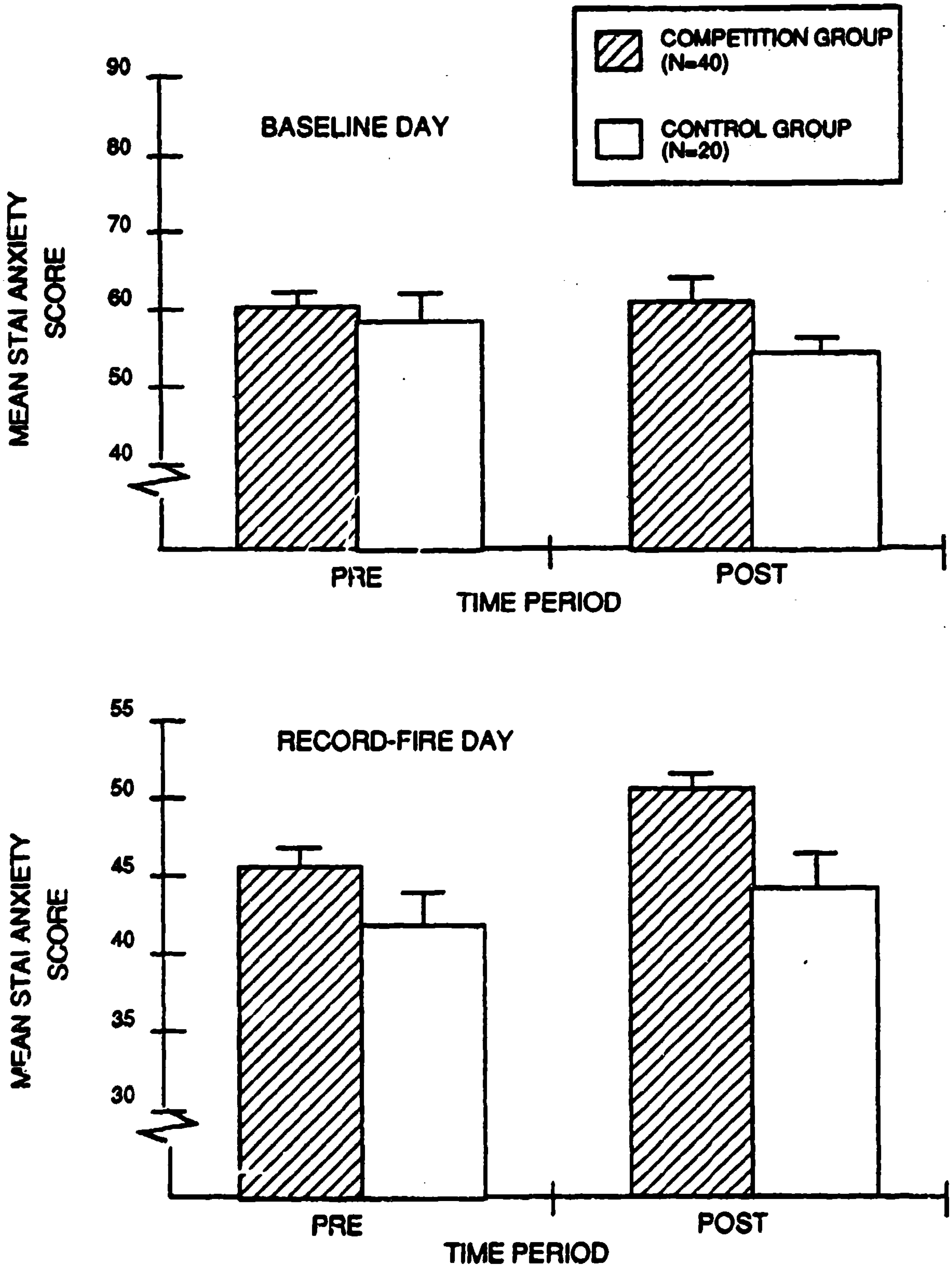
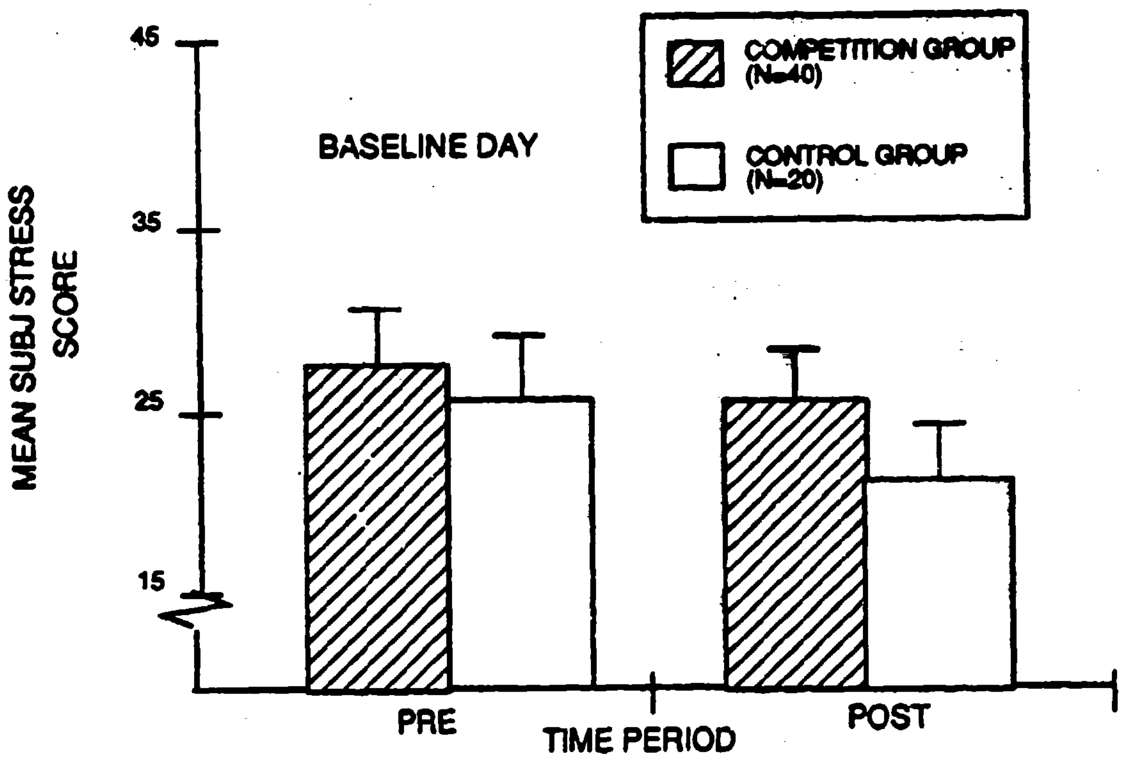


Figure 34. Mean pre- and post-stress STAI Anxiety scores for the Competition and Control Groups on baseline day and record-fire day.



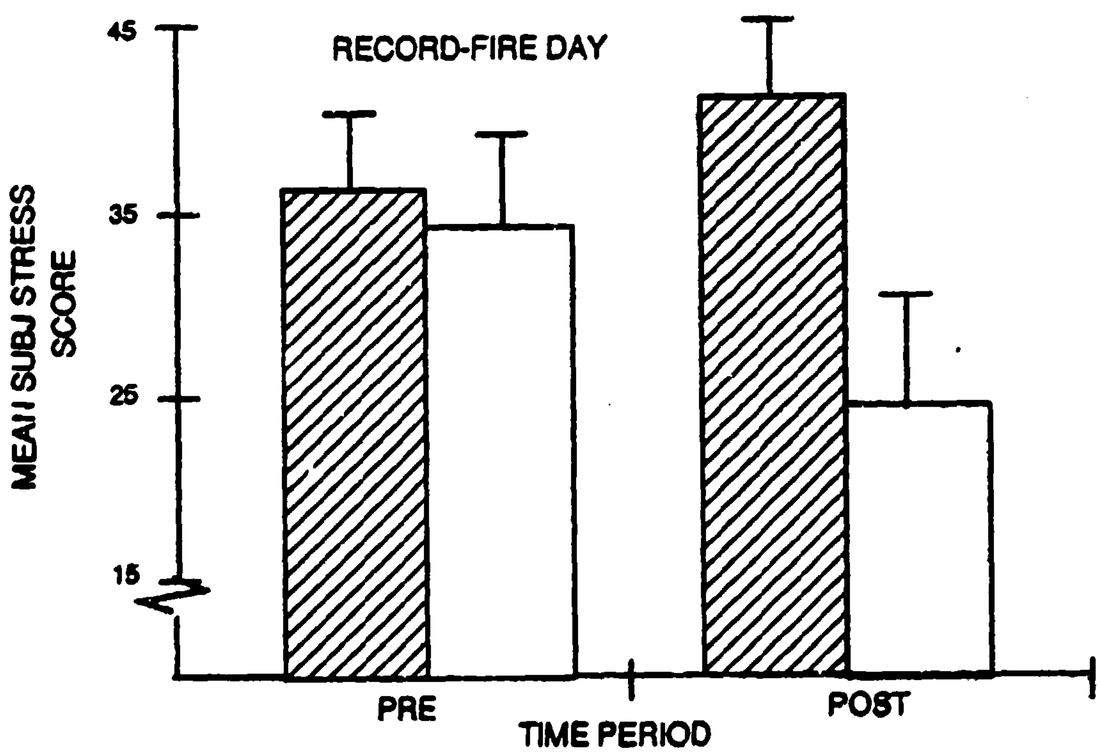


Figure 35. Mean pre- and post-stress Subjective Stress (SUBJ STRESS) scores for the Competition and Control Groups on baseline day and record-fire day.

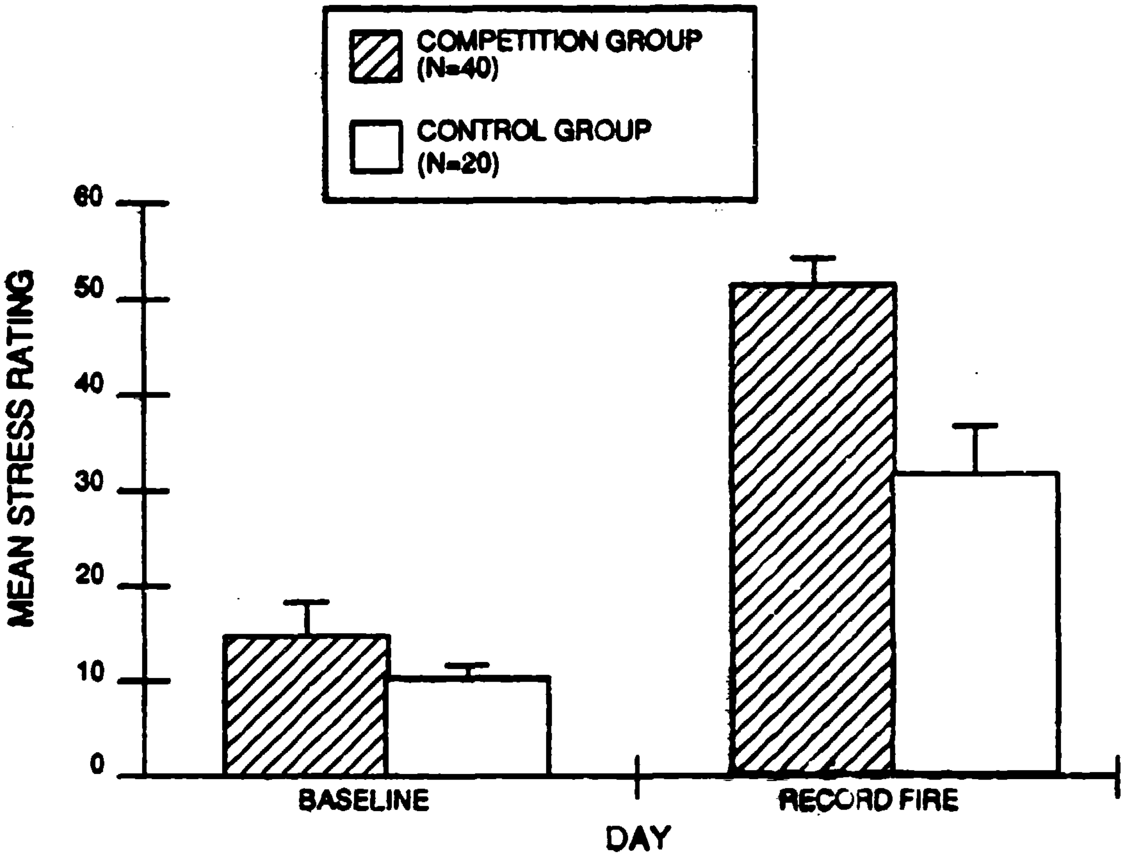


Figure 36. Mean stress ratings from the Specific Rating of Events scale for the Competition and Control Groups on baseline day and on record-fire day.

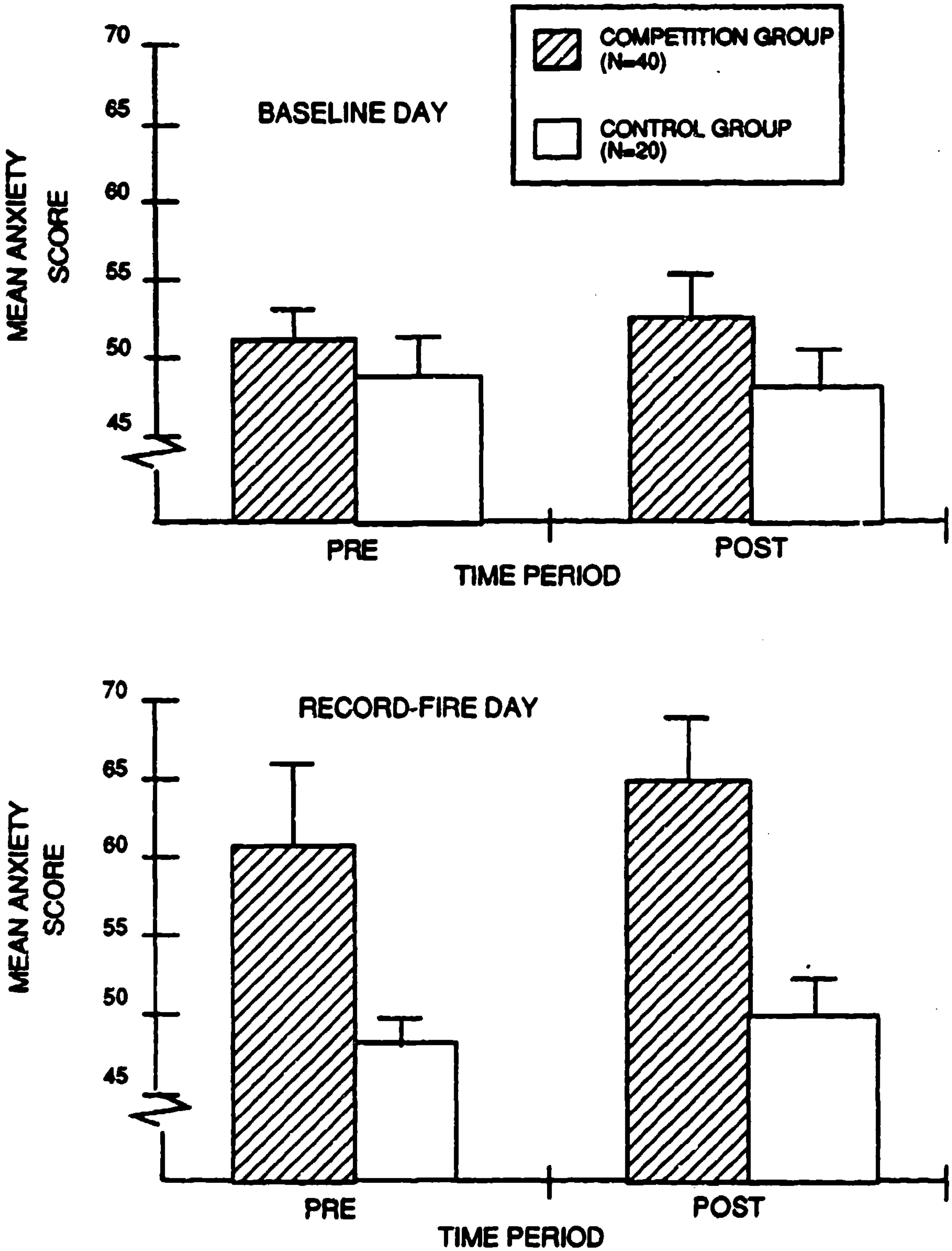


Figure 37. Mean pre- and post-stress MAACL-R Anxiety scores for Competition and Control Groups on baseline day and on record-fire day.

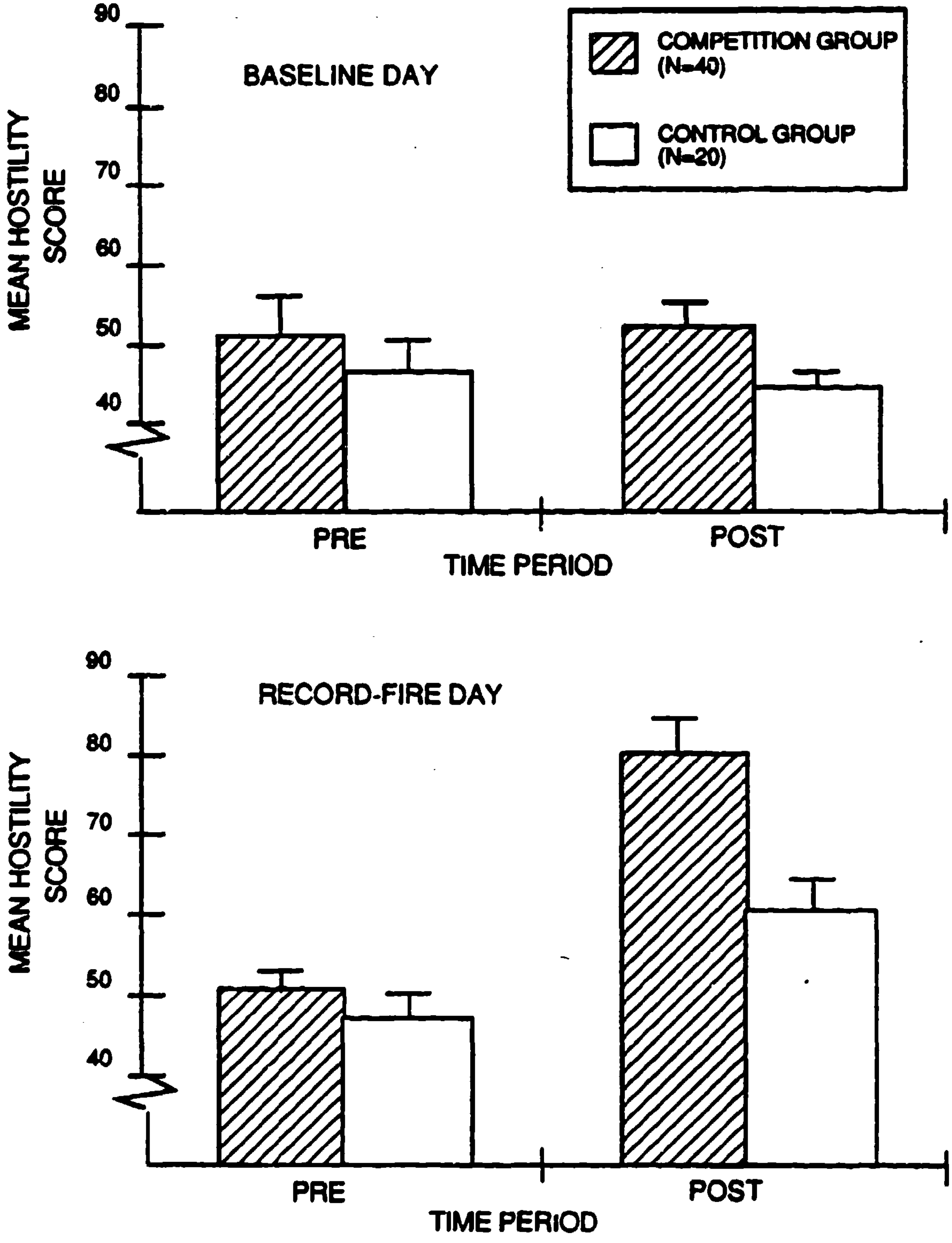


Figure 38. Mean pre- and post-stress MAACL-R Hostility scores for the Competition and Control Groups on baseline day and record-fire day.

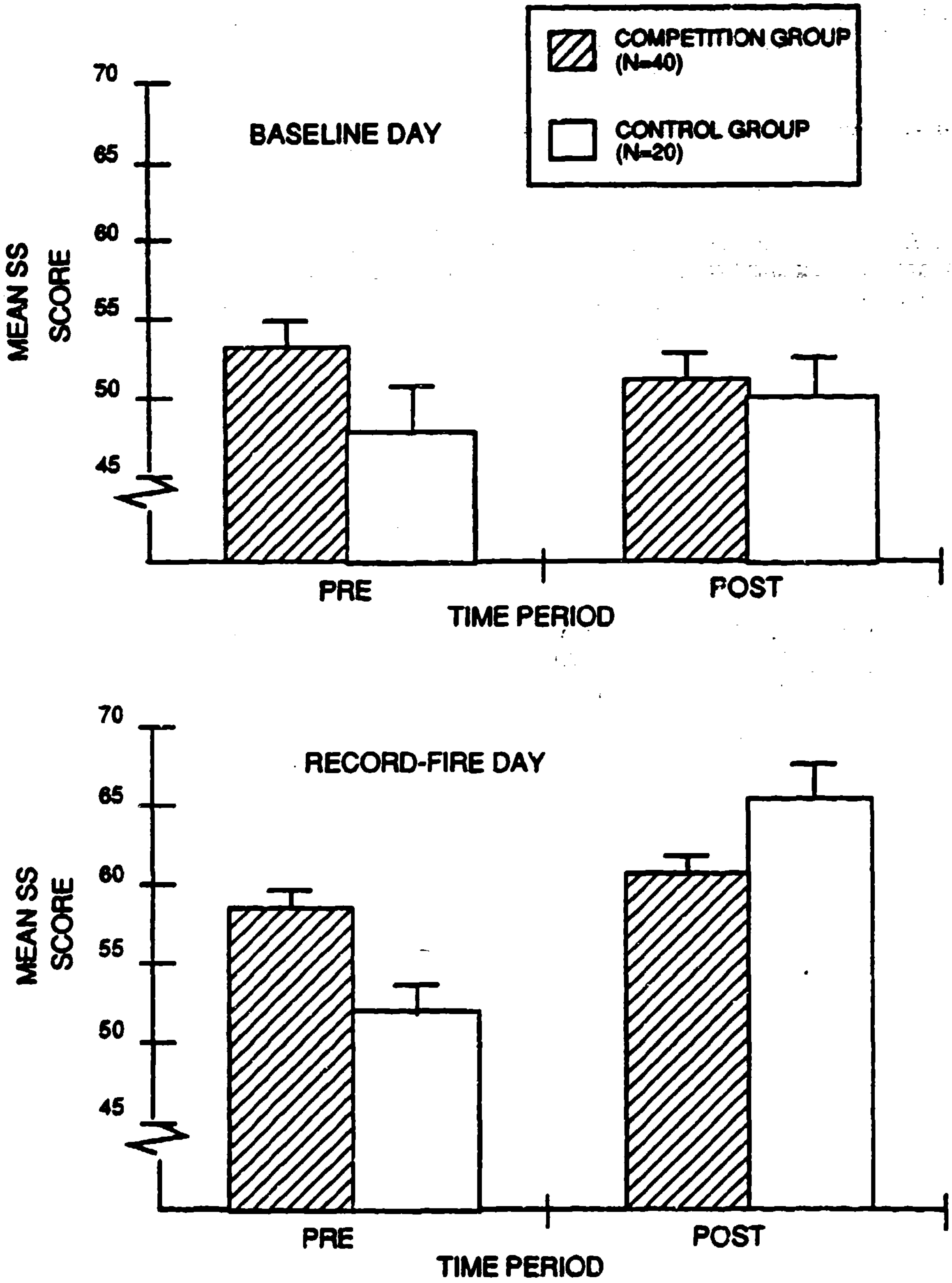


Figure 39. Mean pre- and post-stress MAACL-R Sensation Seeking (SS) scores for the Competition and Control Groups on baseline day and on record-fire day.

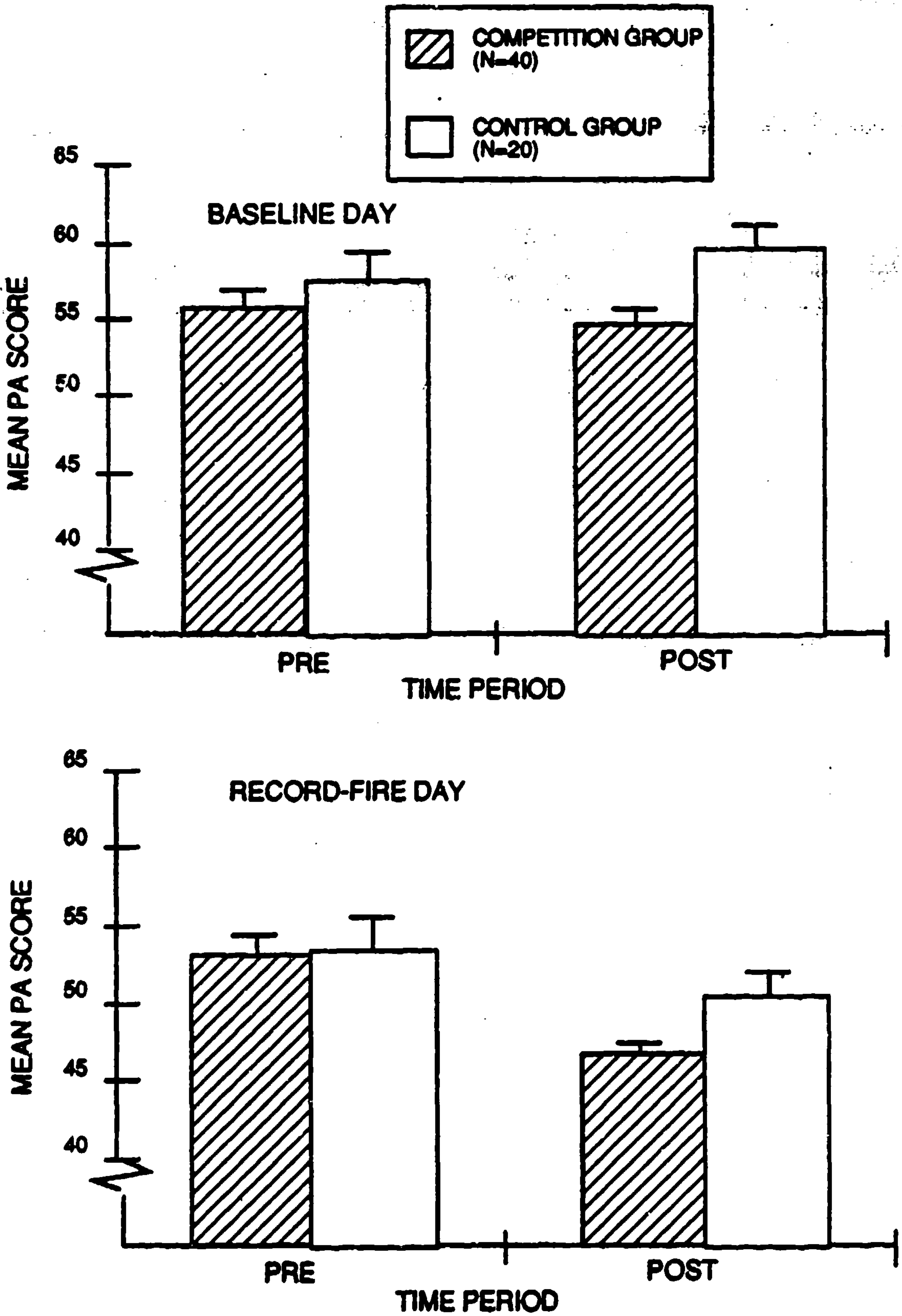


Figure 40. Mean pre- and post-stress MAACL-R Positive Affect (PA) scores for the Competition and Control Groups on baseline day and on record-fire day.

Specific Rating of Events (SRE) (see Figure 36)

As described in the Methods section, the SRE was a post measure given once on baseline day and once on record-fire day. Whereas all other state measures were analyzed using a Groups x Period design, the analysis for this measure was conducted using a Groups x Days design. A Groups main effect indicated that the Competition Group reported significantly higher stress ratings than the Control Group ($F(1,58)= 6.05$, $p=.017$). There was also a significant days main effect that indicated a significant increase in stress ratings from baseline day to record-fire day ($F(1,58)= 68.76$, $p<.001$). Post hoc tests conducted of the Groups x Days interaction ($F(1,58)= 4.56$, $p=.037$) using the modified Tukey HSD Test yielded a critical value for alpha=.01 ($CV_{.01}$) of 12.98 and $CV_{.05}= 9.75$ for group comparisons within days. This indicated that the Competition Group rated the weapon firing significantly more stressful than the Control Group did on record-fire day ($p<.01$).

MAACL-R Anxiety (see Figure 37)

A groups main effect indicated that the Competition Group reported significantly higher Anxiety scores than the Control Group did ($F(1,58)= 11.30$, $p=.001$).

MAACL-R Hostility (see Figure 38)

A groups main effect indicated that the Competition Group reported significantly higher Hostility scores than the Control Group did ($F(1,58)= 7.98$, $p=.006$), and a Period main effect indicated that post-firing Hostility scores were significantly higher than the pre-firing scores ($F(1,58)= 32.95$, $p<.001$). Post hoc tests conducted of the Groups x Period interaction effect ($F(1,58)= 5.26$, $p=.026$) using the modified Tukey HSD Test yielded a $CV_{.01}= 13.77$ and $CV_{.05}= 10.33$ for group comparisons within time period. This indicated that while there were no group differences in Hostility during the pre-firing period, the Competition Group reported post-firing Hostility scores that were significantly higher than the Control Group did ($p<.01$).

MAACL-R Sensation Seeking (see Figure 39)

A significant Period main effect indicated a significant overall increase in Sensation Seeking (SS) ratings from pre to post measures ($F(1,58)= 28.70$, $p<.001$). Post hoc tests conducted of the Groups x Period interaction effect ($F(1,58)= 14.80$, $p<.001$) using the modified Tukey HSD Test yielded a $CV_{.01}= 5.59$ and $CV_{.05}= 4.20$ for group comparisons within time periods. This indicated that the Competition Group reported a significantly higher pre-firing SS level than the Control Group did ($p<.01$), while the reverse is true for the post-firing time period ($p<.05$).

For testing within-group differences across time periods, $CV_{.01}= 4.54$ and $CV_{.05}= 3.40$ for the Competition Group and $CV_{.01}= 6.41$ and $CV_{.05}= 4.82$ for the Control Group. While the Control Group showed a significant increase in Sensation Seeking scores from the pre to post measures ($p<.01$), the Competition Group did not.

MAACL-R Positive Affect (see Figure 40)

A period main effect indicated significant decreases in Positive Affect from the pre to post time periods ($F(1,58) = 37.03$, $p<.001$).

As Figures 34 through 37 illustrate, the response patterns for the STAI Anxiety, the Subjective Stress Scale, and the SRE Anxiety measures are all remarkably similar to the MAACL-R Anxiety measure. Consequently, to avoid repetition, further discussion of statistical results of the anxiety response is based primarily on the MAACL-R Anxiety measure. In addition to the MAACL-R Anxiety subscale, the other MAACL-R subscales (Depression, Hostility, etc.) are discussed.

Comparative Stress Data

As in the previous chapter for the physiological data, the profile of psychological responses obtained from the SS study are compared with profiles obtained in the Surgical and Medical Examination protocols conducted at Northwestern University. All measures compared below are stress perception measures taken on the day of the stress event for the respective protocols (see Figures 41 through 51), except for the Northwestern non-stressed Control Group ("Independent Control"). A MANOVA indicated there were significant differences between the groups for several of the measures (Wilks' $\lambda = .142$; $F(60,419) = 4.54$, $p<.001$). Once again, the Tukey-Kramer modification of the Tukey HSD test was used to conduct the post hoc tests of these measures to determine where the significant group differences occurred.

State Measures

MAACL-R Anxiety

Figures 41 and 42 illustrate how the Anxiety ratings reported by the soldiers in the salvo stress study ("SS Control" and "SS Competition Groups") compared with ratings obtained for the same measure for the groups studied at Northwestern University. Post hoc tests of the pre-stress Anxiety measure yielded a $CV_{.01} = 19.18$ and $CV_{.05} = 16.07$ for comparisons between all the groups. This indicated that both Control Groups reported significantly less anxiety than the exam ($p<.05$) or surgical group ($p<.01$). Post hoc tests of the post-stress Anxiety measure yielded a $CV_{.01} = 17.67$ and $CV_{.05} = 14.81$ for group comparisons. These data indicate that in the post-firing period, the SS Competition Group had a significantly higher level of anxiety than the SS Control Group did ($p<.05$), and had a level of anxiety associated with a moderate level of stress (about comparable to taking a written exam).

MAACL-R Depression

As illustrated in Figure 43 (pre stress), both the SS control and SS Competition Groups reported significantly lower levels of depression than the spouses from the Surgical study (Tukey HSD $CV_{.05} = 10.08$; $p<.05$). Figure 44 (post stress) illustrates that the Independent Control Group (Tukey HSD $CV_{.01} = 22.46$; $p<.01$) and both the SS control and SS Competition Groups reported significantly lower depression levels than the spouses did (Tukey HSD $CV_{.05} = 18.83$, $p<.05$).

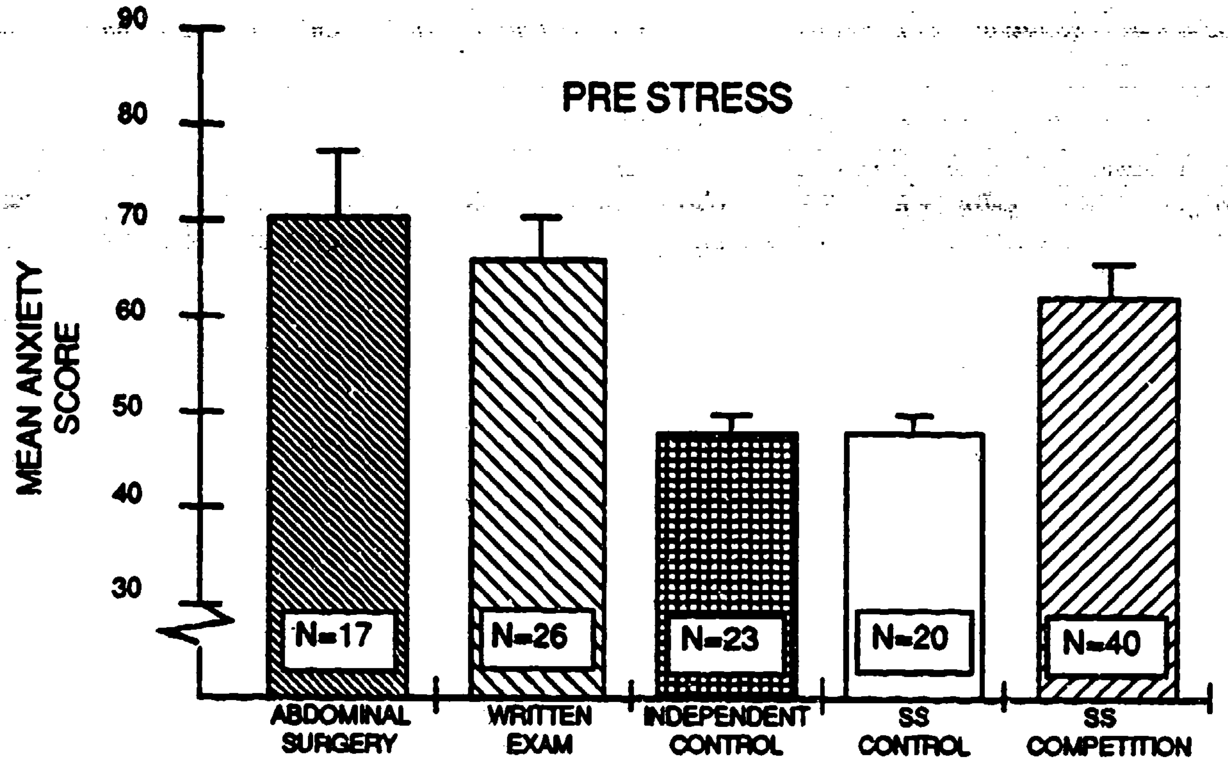


Figure 41. Comparison of mean pre-stress MAACL-R Anxiety for SS Competition and SS Control Groups on record-fire day with those for subjects in the conditions ([1] spouse having serious abdominal surgery; [2] taking an important medical school written exam; or [3] independent non-stress control condition).

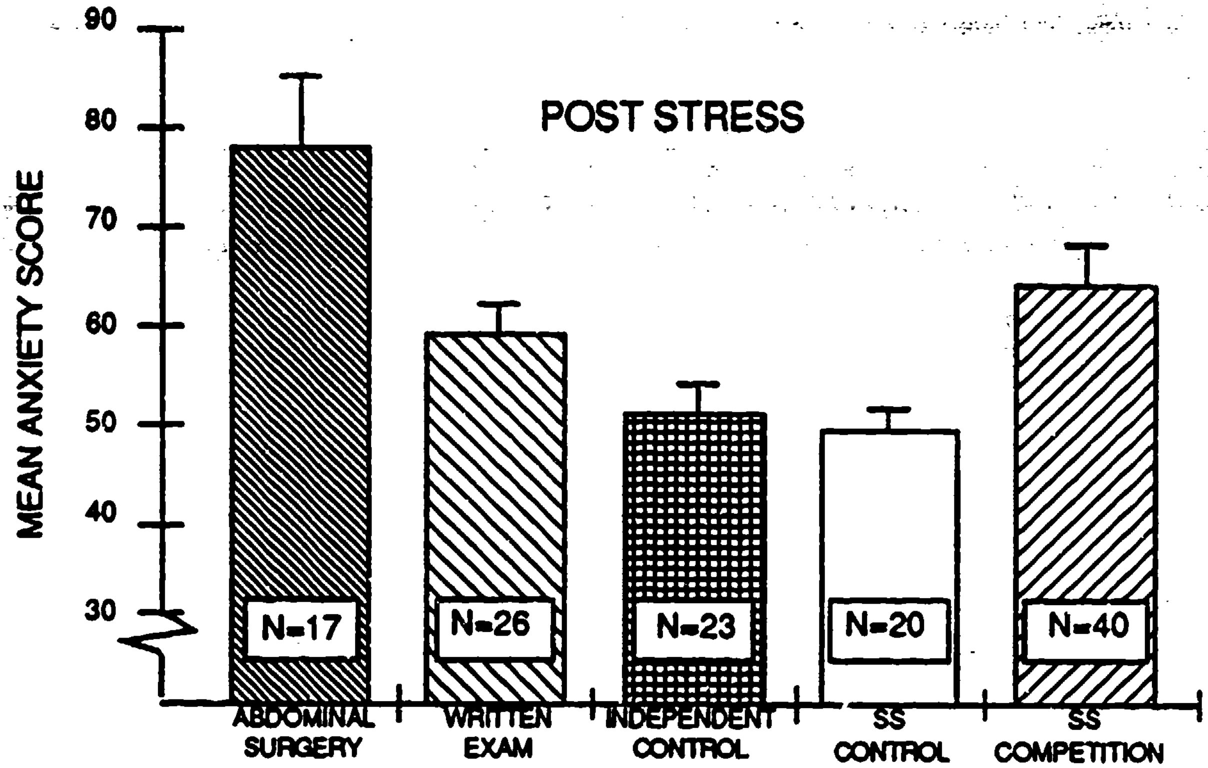


Figure 42. Comparison of mean post-stress MAACL-R Anxiety for SS Competition and SS Control Groups on record-fire day with those for subjects in the conditions ([1] spouse having serious abdominal surgery; [2] taking an important medical school written exam; or [3] independent non-stress control condition).

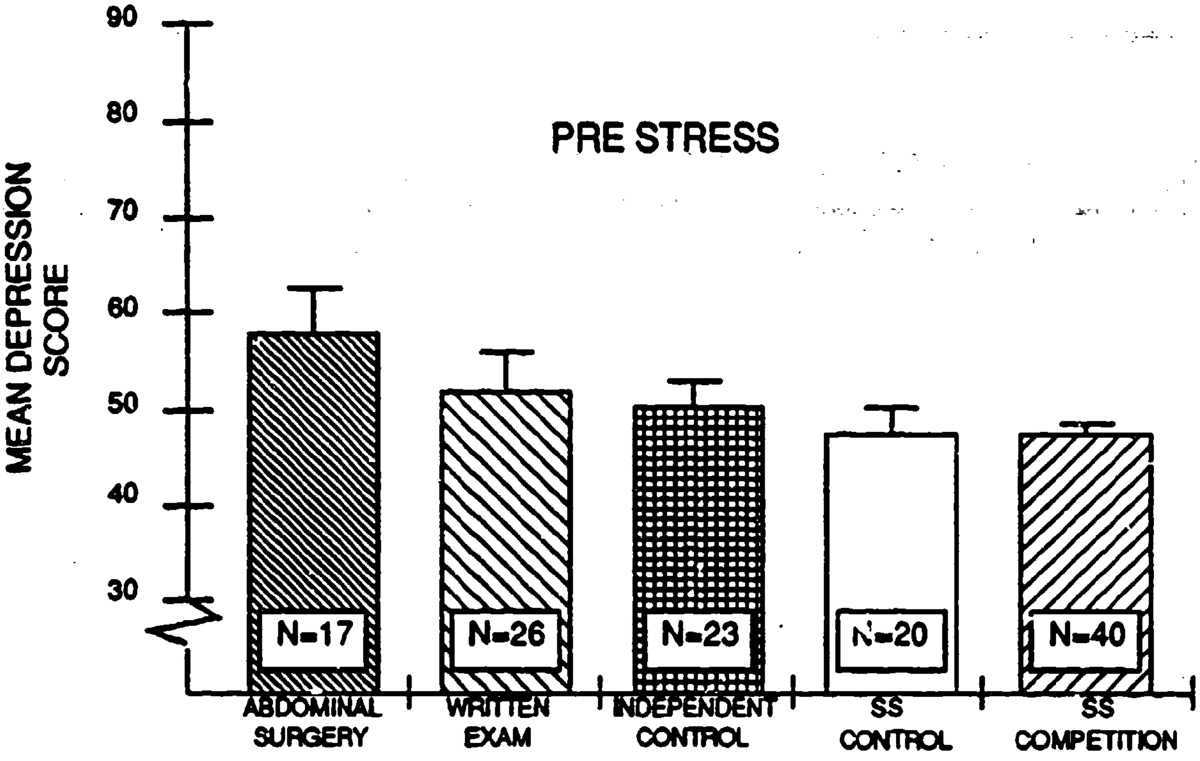


Figure 43. Comparison of mean pre-stress MAACL-R Depression scores for SS Competition and SS Control Groups on record-fire day with those for subjects in the conditions ([1] spouse having serious abdominal surgery; [2] taking an important medical school written exam; or [3] independent non-stress control condition).

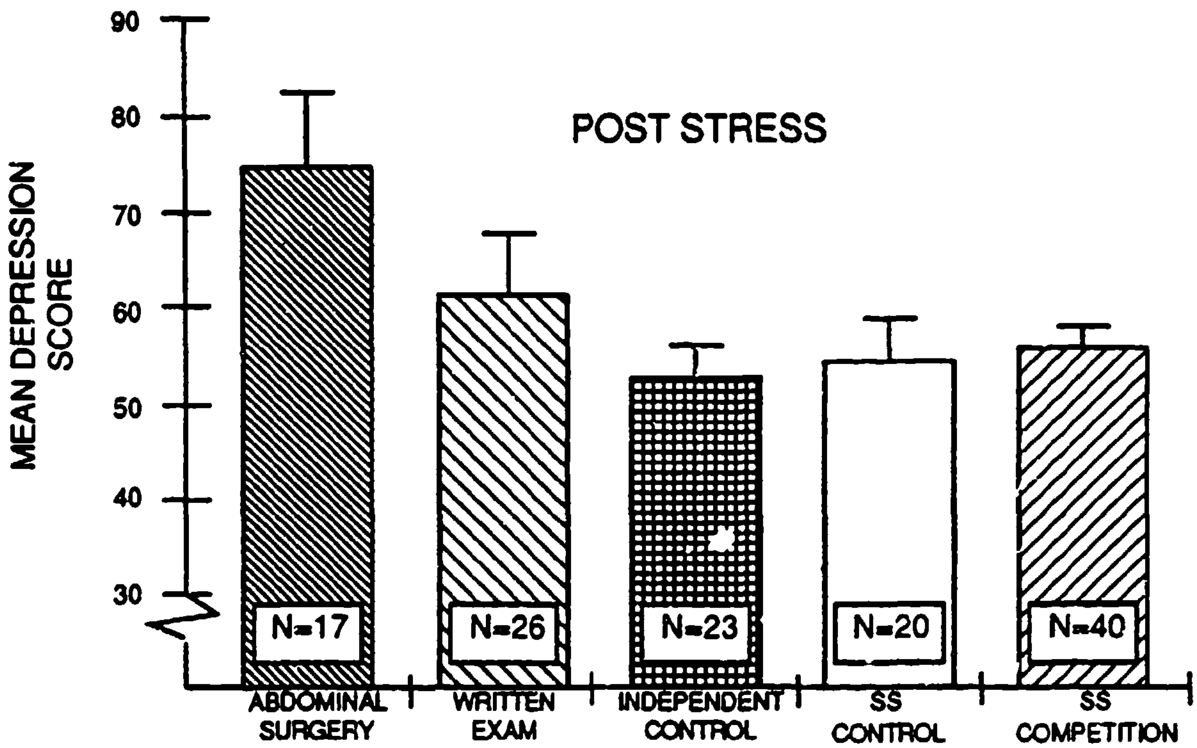


Figure 44. Comparison of mean post-stress MAACL-R Depression scores for SS Competition and SS Control Groups on record-fire day with those for subjects in the conditions ([1] spouse having serious abdominal surgery; [2] taking an important medical school written exam; or [3] independent non-stress control condition).

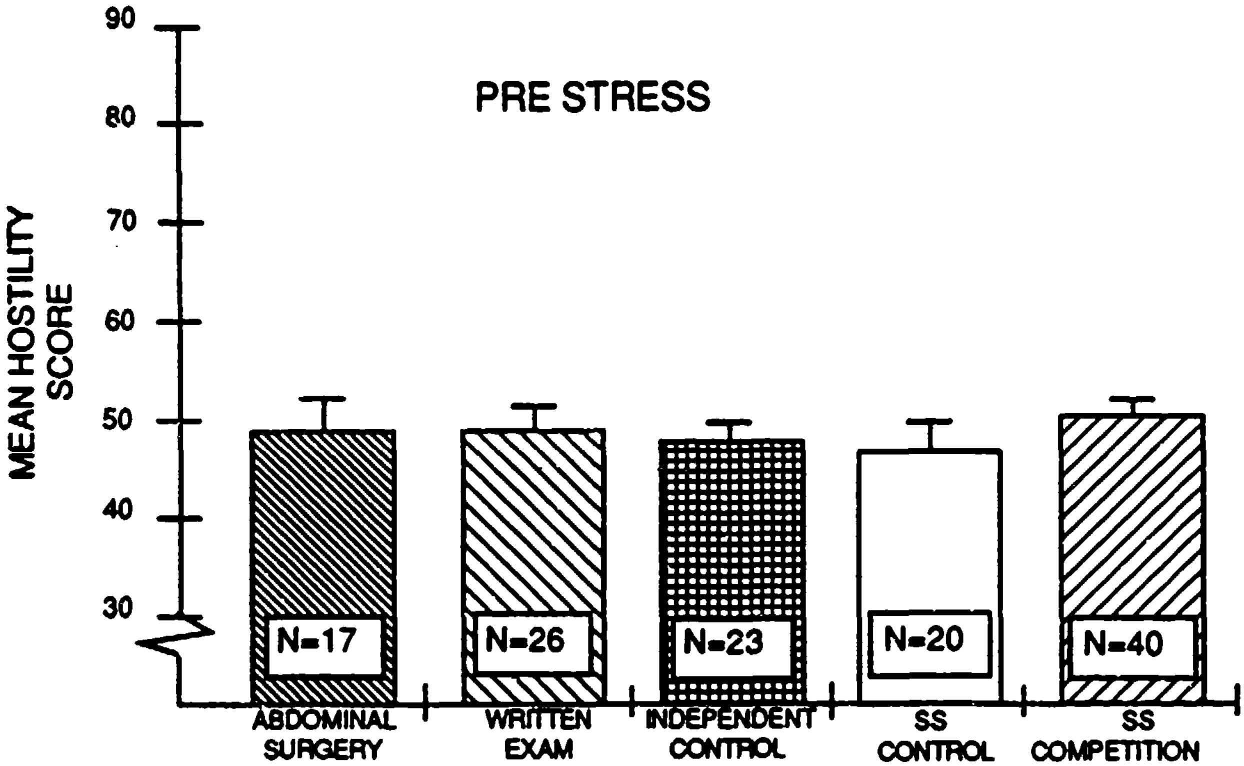


Figure 45. Comparison of mean pre-stress MAACL-R Hostility scores for SS Competition and SS Control Groups on record-fire day with those for subjects in the conditions ([1] spouse having serious abdominal surgery; [2] taking an important medical school written exam; or [3] independent non-stress control condition).

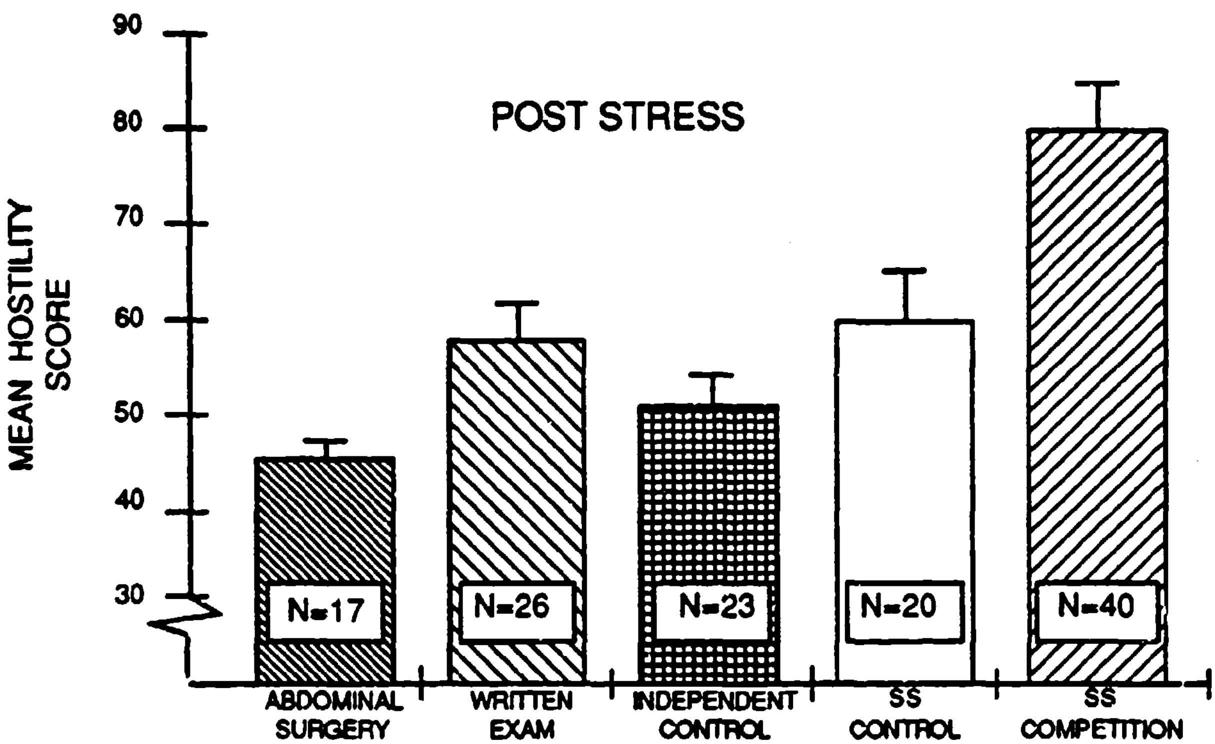


Figure 46. Comparison of mean post-stress MAACL-R Hostility scores for SS Competition and SS Control Groups on record-fire day with those for subjects in the conditions ([1] spouse having serious abdominal surgery; [2] taking an important medical school written exam; or [3] independent non-stress control condition).

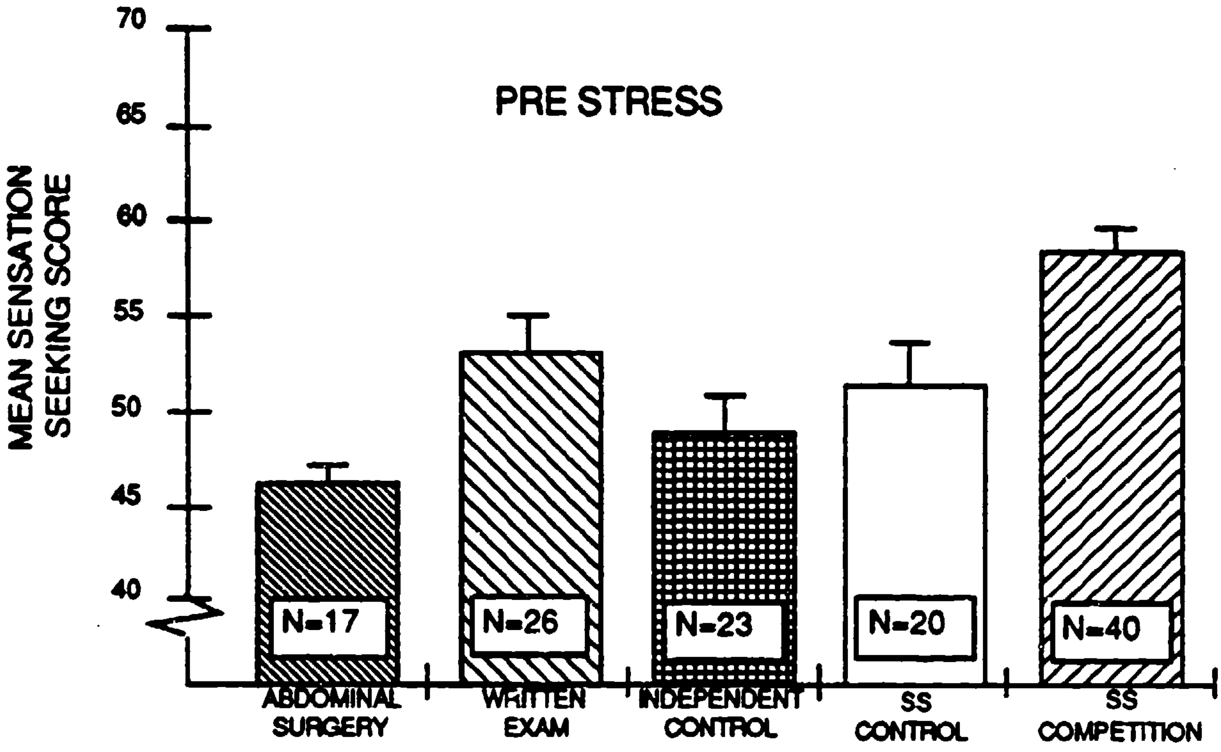


Figure 47. Comparison of mean pre-stress Sensation Seeking scores for SS Competition and SS Control Groups on record-fire day with those for subjects in the conditions ([1] spouse having serious abdominal surgery; [2] taking an important medical school written exam; or [3] independent non-stress control condition).

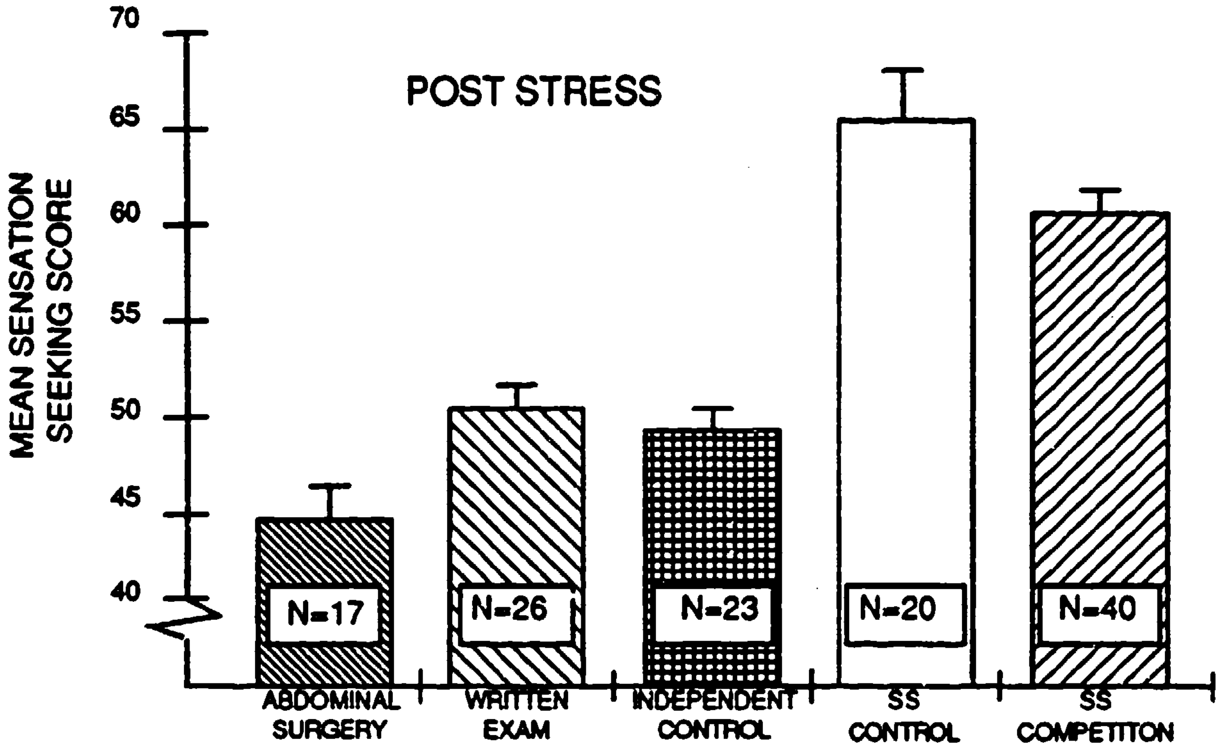


Figure 48. Comparison of mean MAACL-R Sensation Seeking scores for SS Competition and SS Control Groups on record-fire day with those for subjects in the conditions ([1] spouse having serious abdominal surgery; [2] taking an important medical school written exam; or [3] independent non-stress control condition).

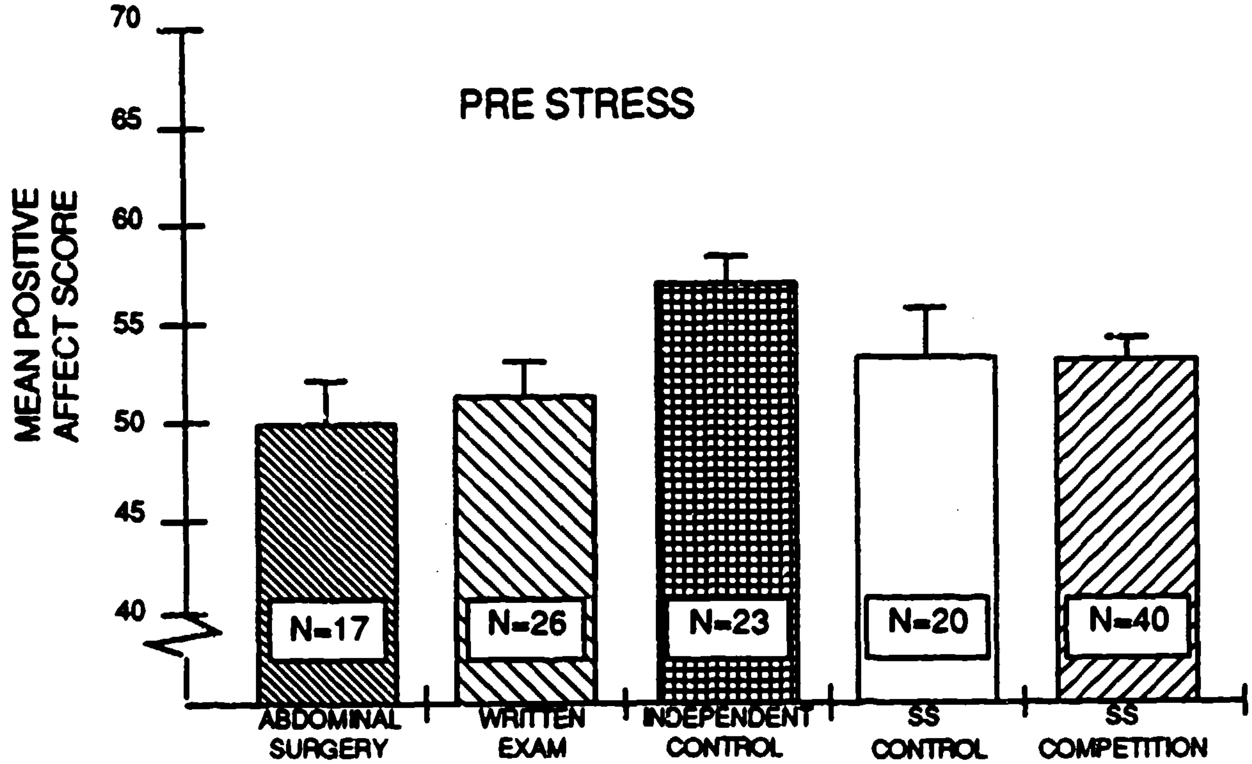


Figure 49. Comparison of mean pre-stress MAACL-R Positive Affect scores for SS Competition and SS Control Groups on record-fire day with those for subjects in the conditions ([1] spouse having serious abdominal surgery; [2] taking an important medical school written exam; or [3] independent non-stress control condition).

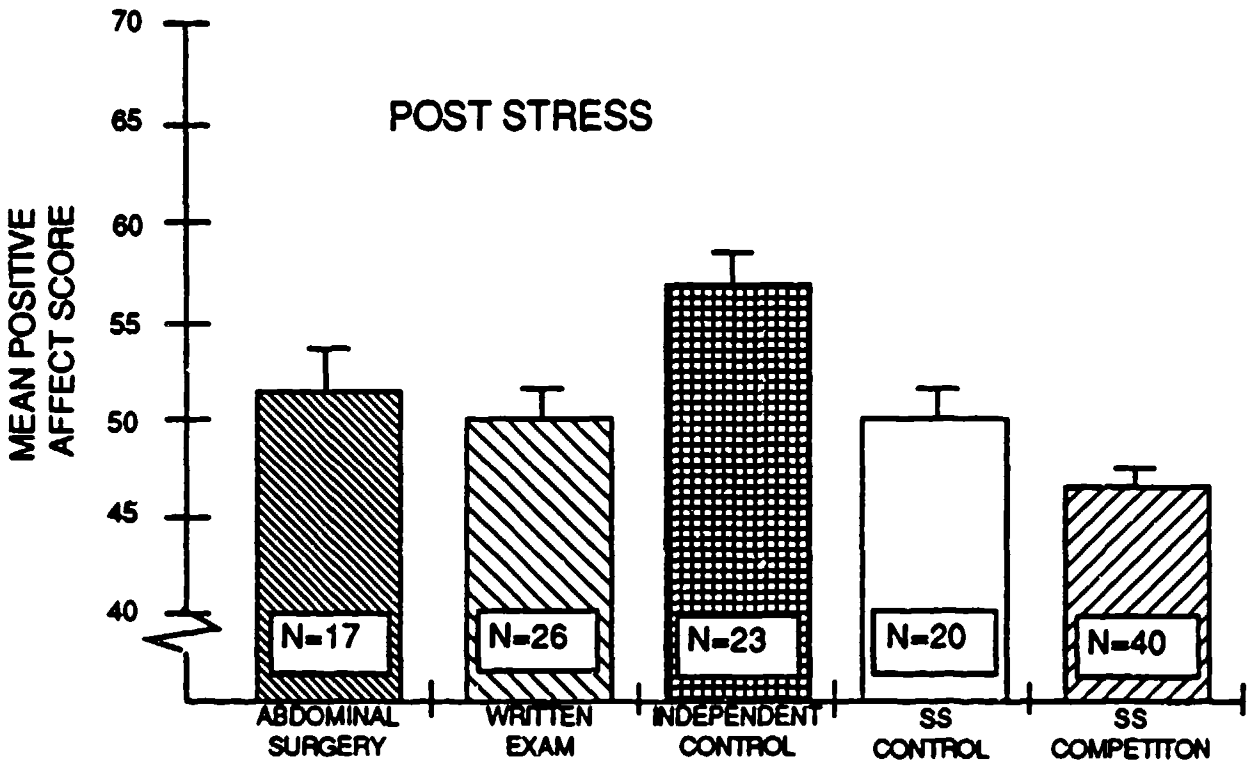


Figure 50. Comparison of mean post-stress MAACL-R Positive Affect scores for SS Competition and SS Control Groups on record-fire day with those for subjects in the conditions ([1] spouse having serious abdominal surgery; [2] taking an important medical school written exam; or [3] independent non-stress control condition).

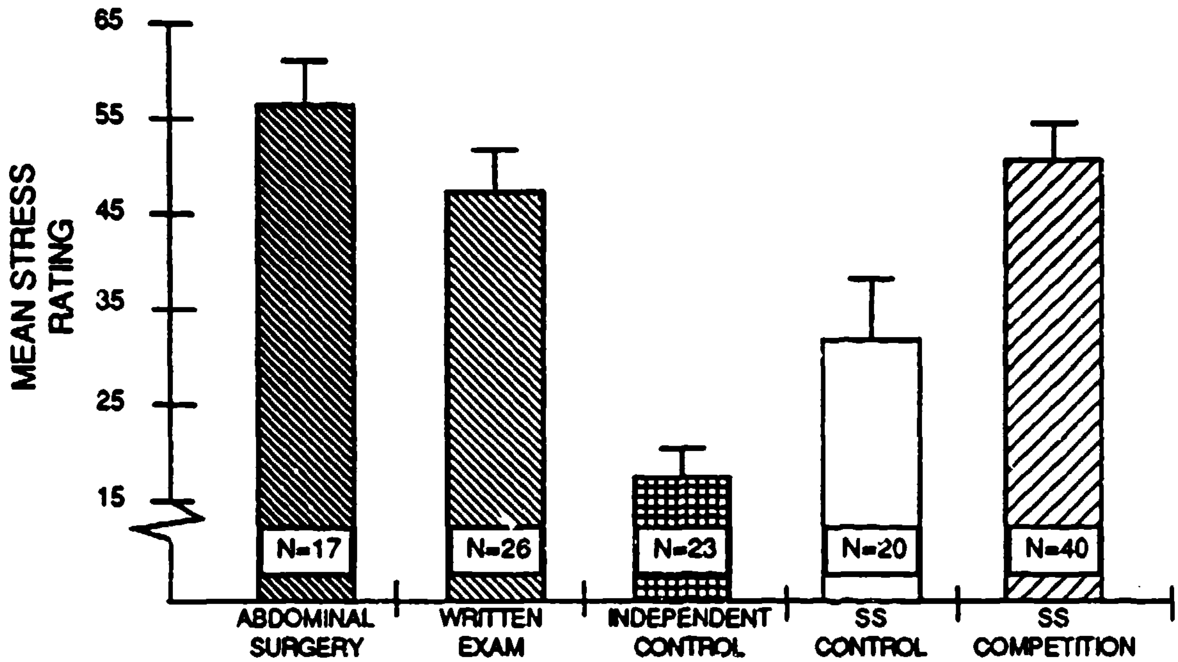


Figure 51. Comparison of mean stress ratings from the Specific Rating of Events scale for SS Competition and SS Control Groups on record-fire day with those for subjects in the conditions ([1] spouse having serious abdominal surgery; [2] taking an important medical school written exam; or [3] independent non-stress control condition).

MAACL-R Hostility

There were no significant differences in Hostility between any of the groups during the pre-stress period (see Figure 45). However, post-stress ratings (see Figure 46) indicated that the SS Competition Group reported significantly higher ratings of Hostility after firing for record than any other group did (Tukey HSD $CV_{.01}$= 19.05; $p<.01$). The SS Control Group did not differ significantly from any group except the SS Competition Group.

MAACL-R Sensation Seeking

Figures 47 and 48 illustrate the difference in Sensation Seeking ratings between the SS groups and those from the Surgical and Examination Studies. Although the SS Competition Group did not differ from the SS Control Group or the Exam Group for the pre-stress Sensation Seeking measure, they reported significantly higher ratings than the Independent control and Surgical groups did (Tukey HSD $CV_{.01}$= 8.60; $p<.01$) for that time period. Both the SS Control and SS Competition Groups reported significantly higher Sensation Seeking during the stress event (post measure) than did any of the other groups studied to date (Tukey HSD $CV_{.01}$= 7.86; $p<.01$).

MAACL-R Positive Affect

There were no significant group differences in pre-stress Positive Affect (see Figure 49). However, as illustrated in Figure 50 (post stress), both SS groups and the Exam group reported significantly lower Positive Affect than the Independent control did (Tukey HSD $CV_{.05}$= 6.00; $p<.05$).

Specific Rating of Events

The SS Competition Group reported significantly higher stress ratings than the SS Control Group (Tukey HSD $CV_{.05}$= 19.09; $p<.05$) and the Independent Control Group did (Tukey HSD $CV_{.01}$= 22.78; $p<.01$) and stress ratings similar to the those reported by the Surgical and Exam groups (see Figure 51). Although the SS Control Group did not report stress ratings that were significantly different from those of the Independent Control Group or the Exam group, they experienced significantly less stress than the Surgical group did (Tukey HSD $CV_{.01}$= 22.78; $p<.01$).

Components of Negative Affect

Results from the above analyses of group differences and from the comparative stress data indicated particularly high post-stress hostility levels for the SS Competition Group. In the SS study, individual performance was at stake and well publicized, creating a situation that was more of a personal threat to the ego versus one that involved an indirect threat or concern for another person's welfare (e.g., spouses in the Surgical study). Therefore, it appears that the soldiers' expectations of how they should perform and their appraisals of how well they were performing were expressed as components of negative affect.

As stated earlier, the three components of negative affect include hostility, depression, and anxiety. Zuckerman (personal communication, April 3, 1989) defined hostility as "the individual's frustration level," depression as "a personal sense of failure," and anxiety as "a measure of uncertainty." Based on the SS results, it appears that in a situation involving the evaluation of individual performance, two components of negative affect, frustration level and sense of failure, tend to dominate as factors reflecting a more self-oriented perception of the stressfulness of the situation. For example, the individual will experience either a sense of frustration or failure based on a combination of his or her personal expectations of how well s/he should perform and his or her appraisal of how well s/he is performing.

Uncertainty, on the other hand, appears to relate more to the individual's perception of the circumstance or situation and lack of information about what might happen. This reflects a more externalized process, a "what if" phenomenon, as opposed to the more internalized process ("I know I'm not doing well") reflected in the self-oriented dimension of negative affect.

In a series of investigations of variations in affect of Army platoons undergoing basic combat training (BCT), a divergence between components of negative affect at certain stress points in the BCT cycle has been reported. To describe the relationship between the two distinct processes of stress perception (self-oriented versus external) for the SS subjects, an affect divergence score was devised. MAACL-R Hostility and MAACL-R Depression scores were combined, and MAACL-R Anxiety was then subtracted (affect divergence score = [Hostility + Depression] - Anxiety). A divergence between the Hostility + Depression total and the Anxiety score would result in a high score on the affect divergence score. This would indicate a relatively high level of frustration and sense of failure with relatively little uncertainty. This new measure was included in the correlation matrix used below to evaluate relationships between psychological measures and performance.

Correlations with Performance

Pearson's correlation coefficients were computed for the SS groups between the performance measures (the number of targets hit in the semiautomatic and burst modes) and the military experience, psychological, and coping measures. As indicated in Table 4, correlations were computed for all 60 subjects for the military experience and trait variables. However, correlations were computed separately for the Competition Group (*N*=40) and the Control Group (*N*=20) for the state-related variables. Performance was measured by the number of targets hit in each mode. The total number of possible hits was 72 per mode.

Performance and Military Experience

Since no significant differences between groups were found for the military experience variables, Pearson correlation coefficients were computed between these variables and performance for the combined SS groups. As shown in Table 4, length of service and current weapons qualifications correlated significantly and positively with performance. While a longer length of service was associated with better burst mode performance, the number of weapons for which the soldier was currently qualified was positively correlated with semiautomatic mode performance.

Table 4

Significant Correlations With Performance

Measure	Group	Correlations with performance (SM[a], BM[b])
Military experience	All (N=60, df=58)	Length of Service/BM, r = +0.33* Current Weapons Qualif/SM, r = +0.26*
Trait measures	All (N=60, df=58)	MAACL-R Depression/SM, r = -0.31* MAACL-R Hostility/SM, r = -0.29* MAACL-R Negative Affect/SM, r = -0.36**
Coping measures (record-fire day)	Control (N=20, df=18)	AVOID/BM, r = -0.46*
State measures (post) (record-fire day)	Competition (N=40, df=38)	MAACL-R Sensation Seeking/SM, r = +0.55** MAACL-R Sensation Seeking/BM, r = +0.41** Affect Divergence Score/SM, r = -0.33* Affect Divergence Score/BM, r = -0.35*
	Control (N=20, df=18)	MAACL-R Hostility/BM, r = -0.46* Affect Divergence Score/BM, r = -0.50

[a]SM = Targets hit in semiautomatic mode
[b]BM = Targets hit in burst mode
* = $p<.05$
** = $p<.01$

Performance and Psychological Responses

Trait Measures

As indicated in Table 4, Trait Depression and Trait Hostility were both significantly and negatively correlated with performance in the semiautomatic mode of fire. In other words, individuals who reported feeling "generally" depressed or hostile did not perform as well in the semiautomatic mode as those with lower trait Depression and Hostility.

Coping Measures

Separate Pearson correlation coefficients were computed for the Competition and Control Groups between the coping measures and performance scores. There were no significant correlations between baseline day coping measures and record-fire day performance. There were, however, significant correlations between coping measures obtained on record-fire day and performance. As indicated in Table 4, a significant negative correlation was found between the Avoidance subscale of the RWCCL and burst mode performance for the Control Group only. Those individuals who reported sleeping whenever they could and generally avoiding others did not perform as well as those who were more situationally oriented.

State Measures

Separate correlations were also performed for the Competition and Control Groups for the stress perception measures. Once again, there were no significant correlations between baseline day state measures and record-fire day performance. There were, however, significant correlations between state measures obtained on record-fire day and performance. As indicated in Table 4, Sensation Seeking scores (post measure) were positively correlated with both semiautomatic and burst mode performance for the Competition Group. While negative correlations were found between post-firing Hostility scores and burst mode performance for both groups, the correlation was significant for the Control Group only.

The Affect Divergence Score, however, proved more sensitive, correlating significantly and negatively with performance for both the Competition and Control Groups. Those soldiers who felt they were not performing according to their own or other's expectations appeared to feel more frustrated. Those who were more critical of themselves during the task were not performing as well in the semiautomatic mode as those who were not.

Individual Differences

Trait Measures

To address the effect of individual variability in stress response, cluster analysis was performed using Version 4.[illegible] of the statistics software package, SYSTAT (Wilkinson, 1988). Cluster analysis is a method of statistically grouping subjects based on the dependent measures (e.g., evaluating whether the subjects tend to fall into groups having similar characteristics). It minimizes the variance for each cluster across the measures so that the result is groups or clusters of individuals that are most alike.

When cluster analysis was performed of the personality measures of the entire SS group, two distinct clusters of individuals emerged: one with a high stability (and low emotionality) profile, and the other with a relatively low stability (and high emotionality) profile (see Figure 52). There were equal proportions of subjects from each SS group within each cluster. A MANOVA was conducted of the performance measures (semiautomatic and burst modes) to test the effects and interactions of Trait Clusters (High and Low Stability Profiles) x Groups (competition and control). While there was no significant group main effect (Wilks' λ = .991; $F(2,54)$= .25, p=.783) and no significant Cluster x Group interaction effect (Wilks' λ = .997; $F(2,54)$= .08, p=.925), there was a significant Cluster main effect (Wilks' λ = .858; $F(2,54)$= 4.47, p=.016). Individuals with a trait profile of higher scores on the Positive Affect subscale, lower scores on Negative Affect subscale, less External Locus of control, and higher stability (EPQ-P and N), performed significantly better in semiautomatic mode ($F(1,55)$= 7.33, p=.009) than those with a profile of lower Positive Affect, higher Negative Affect, more External Locus of control, and less stability (see Figure 53). Individuals in the high stability profile (Cluster 1) also reported using Problem-focused coping on record-fire day significantly more often ($F(1,55)$= 4.45, p=.039) than those in Cluster 2, the low stability profile.

DISCUSSION

In the previous chapter about hormone responses, it was concluded that the subjects in the competitive condition were significantly more stressed physiologically than those in the control condition. Some of the physiological indices reflected this more than others did. Similar findings were obtained using the psychological response patterns. The psychological responses obtained in the SS study have provided a more comprehensive evaluation of the use of competitive marksmanship as part of a methodology for generating stress.

Significant differences between the Competition Group and the Control Group in stress perception measures on record-fire day demonstrate that competition can be used to reliably produce a moderate level of stress in soldiers. Pre- and post-measures of state anxiety (MAACL-R Anxiety, STAI Anxiety, Subjective Stress Scale, and Specific Rating of Events) all indicate that the Competition Group was experiencing significantly more stress than the Control Group.

Pre-firing Sensation Seeking ratings were also significantly higher for the Competition Group. This measure corresponds to self-rating descriptions of an "excited anticipation" affect (Zuckerman & Lubin, 1985). These subjects may have been in a state of excitation or one of "anticipatory vigilance" described by Arthur (1987) as a state of arousal that allows the organism to assess an impending stress and choose a method of coping with it. Perhaps the activity and arousal level of the competitors was elevated by the entire record-firing scenario to place them in a state of "readiness" for competition.

There were also significant group differences in post-firing Hostility ratings. State Hostility ratings for the SS Competition Group were the highest of any group. While increases in hostility do not seem to be part of the anticipatory response, they do occur immediately afterward in response to more well-defined and perhaps negatively perceived aspects of the outcome. The SS study included both public and personal performance evaluations creating a potential for heightened personal vulnerability. How the

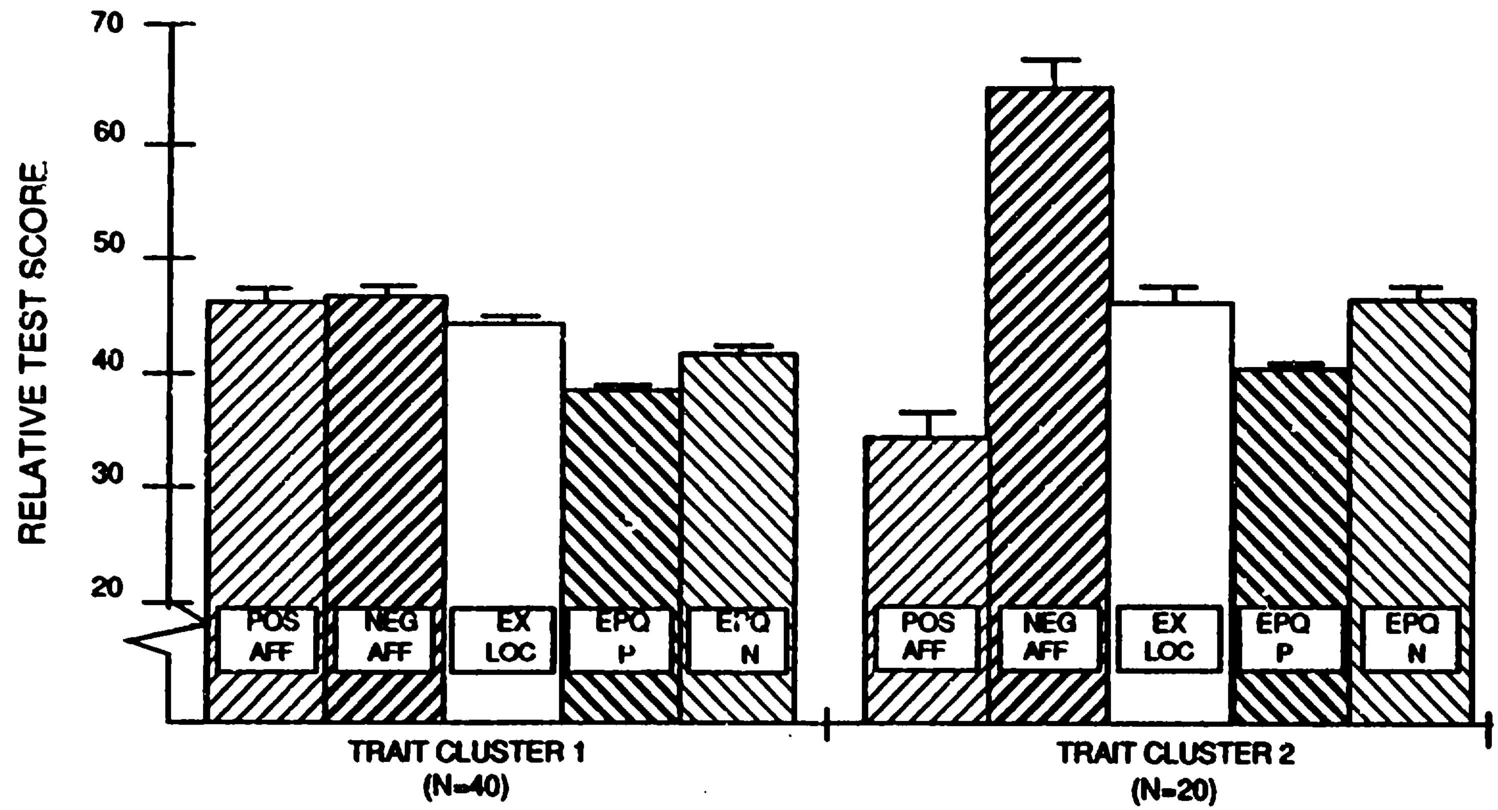


Figure 52. Mean relative test scores for two personality clusters indicating a high stability profile (Cluster 1) and a low stability profile (Cluster 2).

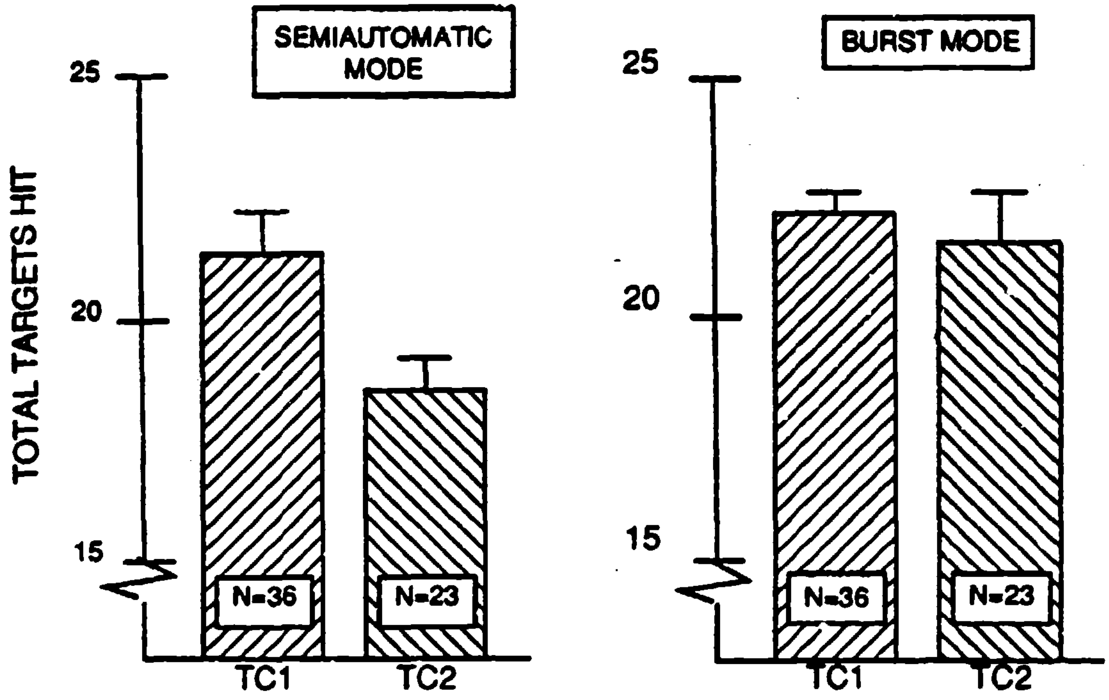


Figure 53. Performance scores (total targets hit per mode) for the two personality clusters (Trait Clusters 1 and 2, "TC1" and "TC2") obtained from the combined SS groups.

individuals rated their response to the stress event (indicated by the post measures) appeared to depend on the influence of intervening perceptual factors including personal expectations and demands combined with appraisals of how well they did.

Although the soldiers rated the competition as moderately stressful, the overall level of distress was apparently not enough to affect their record-firing performance. Wilkins (1982) stated that not only must a situation be of a given intensity to lead to stress, it must also be of a given kind for a particular person. The SS study consisted of top-notch Airborne troops highly qualified for the task of firing for record. In other words, the task demands alone would not necessarily have an overwhelming effect on marksmanship performance. Some emphasis must be given to the individual reactions of the soldiers during the weapon firing. In addition to the individual's expectations or demands of himself, we must take into account his ongoing assessment of his possible success or failure (Wilkins, 1982).

The Affect Divergence Score provides an understanding of the dynamics occurring with some of the intervening perceptual factors. A high score for this measure indicated a divergent relationship between the level of perceived failure combined with frustration, and the level of uncertainty involved in the task. The significant negative correlations obtained with performance indicated that the soldiers were affected more by their realistic self-critique processes than by the uncertainty of the task outcome.

The divergent relationship within the Affect Divergence Score is consistent with results obtained by Datel and Engle (1966) when evaluating changes in nagative affect in a platoon undergoing basic combat training (BCT). Using the MAACL (Zuckerman & Lubin, 1965), Datel and Engle found a divergence between MAACL Hostility and MAACL Anxiety at certain stress points in the BCT cycle. During the first 3 weeks, anxiety subsided as hostility increased, while during the last 2 weeks, hostility subsided and anxiety increased. This supports the notion that if the individuals' assessment of their progress (BCT or other performance) is accomplished primarily through repeated self-critiques, the hostility component of the negative affect would increase. However, if the individual focuses more on the nature of the situation such as uncertainty of outcome or lack of information, the anxiety component would increase. The Affect Divergence Score provided an opportunity to assess the interactive relationship between these specific affects. The significant correlations found between the Affect Divergence Score and performance indicated that the measure is more sensitive to the individual's perception of the situation than to any of the three components of negative affect taken separately.

Cluster analysis of the personality measures of the total group revealed subgroups of subjects with two distinct personality profiles: a high stability profile consisting of high Positive Affect ratings, low ratings on the Negative Affect subscale, and less instability (lower EPQ-P and N); and a relatively low stability profile of the corresponding trait measures. Lower external locus of control was also associated with the low stress profile. Johnson and Sarason (1979) pointed out that the most studied personal resource variables in stress research are locus of control and sense of mastery. The perception of events as controllable is associated with less adverse outcomes. This notion is supported by the SS personality profiles because the subjects in the high stability profile perceived themselves as being more internally motivated and used significantly more problem-focused coping than did the remainder of the subjects.

When the significant negative correlations obtained between trait depression and hostility and performance are considered, it may be reasonable to conclude that the payoff for individuals with the high stability profiles is significantly better performance in the semiautomatic mode of fire. Although there is no evidence of a direct relationship between personality traits and soldier performance, the role of significant moderating variables (e.g., coping strategies) as possible links between traits and performance must be considered. In a study by Vickers, Kolar, & Hervig (1989), personality assessments and coping assessments were made for two samples of recruits going through U.S. Navy basic training. They reported that the personality trait of conscientiousness was related to active problem-solving efforts, while neuroticism was related to self-blame and wishful thinking. After a review of studies that also investigated personality and coping dimensions, they postulated that the link of stable psychological traits to situational coping reactions may influence morale, performance, and health. Until this is explored further, there remains a need for further assessment of the use of personality profiles for the prediction of performance during stressful conditions.

In trying to predict responses to a stress event, it is necessary to consider the kind and intensity of stress and the time of measurement, along with the personal factors that might account for the individual variability in stress response. Appley and Trumbull (1977) found that relatively consistent intra-individual, but varied inter-individual, psychobiological response patterns occur in stressful situations. The impact of these response patterns on performance is not readily predictable from a knowledge of the situational conditions alone, but requires an analysis of the extent of individual variability in the context in which the stressor is applied.

A major contribution of the HEL Stress Research Program is the identification of critical psychological and physiological factors for use as indices against which other stressors can be evaluated. The data obtained using the MAACL-R subscales and the SRE, for example, measure a variety of affective components within the "stress experiences" across studies. In addition to being reliable and efficient to use, these measurements are valuable tools in investigating individual differences in response to stress. Further relationships between the psychological data and corresponding responses obtained from the physiological measures are discussed in Chapter 6. The response profiles that have emerged from the SS study, in conjunction with the Surgical and Exam Studies, have brought us closer to identifying the significant factors that can help develop an optimum methodology for prospective stress research.

CHAPTER 5

HEART RATE RESPONSES TO COMPETITION
(J. Mazurczak, S. Wansack, J. M. King)

INTRODUCTION

Human heart rates change in response to exercise (Sheffield & Roitman, 1976) and in response to a variety of psychological stressors (Gunn, Wolf, Block, & Person, 1972). The lability of this response system means that it is valuable in capturing brief responses to external events.

While biathlon shooters perform best at the elevated heart rate to which they became accustomed during training (O'Leary, 1980), studies of competitive shooters have generally suggested that lowered heart rates are associated with superior performance (Wilkinson, Landers, & Daniels, 1981; Tretilova & Rodmiki, 1979; Landers, 1980; Yur'yev, 1985). Exercise has also been found to degrade the aiming and shooting performance of noncompetitive military shooters (e.g., Torre, 1966). Thus, relatively lower heart rate has generally been linked to better shooting performance. The authors were therefore interested in evaluating techniques to measure heart rate in military shooters.

The decision to implement heart rate measurements in this experiment was made relatively late in the planning process. Since the devices to be used were new to the investigators, this portion of the study was implemented as pilot work.

The objectives of this work were (a) to evaluate the utility of the UNIQ™ HeartWatch and related devices in field settings, and (b) to obtain a preliminary assessment of the degree to which heart rate measurements could contribute to HEL stress profiles.

METHODS

Subjects

The subjects in this subexperiment were 12 infantrymen, six each from the Competition and Control Groups, who had volunteered to participate in the SS study and who had further volunteered to wear the HeartWatches and to have their heart rates monitored.

Apparatus

The subjects wore the HeartWatch sensors and the HeartWatch data-logging watches. The sensors were strain gauges worn around the subjects' chests that transmitted the signals to the HeartWatch, which stored the data for later transfer into a Zenith 248 computer using the model 8799CI computer interface module, where they were saved as ASCII files. The HeartWatch sensors, data-logging watch, and computer interface are available from Computer Instruments Corporation, 100 Madison Avenue, Hempstead, New York 11550. The other apparatus germane to this subexperiment is described elsewhere in this report.

Procedures

The general procedures for this subexperiment have been described in the General Method section of Chapter 1 and in the other chapters of this report. Heart rate data were obtained from six competition stressed subjects (from the third week of the experiment) and from six control subjects (from the second week of the experiment). Heart rate data were sampled during familiarization firing during baseline day for an average of 6.5 minutes and during record firing on record-fire day for an average of 14.3 minutes. The actual sampling duration depended on the time required for each subject to complete the firings. The watches were set to sample heart rate every 15 seconds. Before analysis, the data stored in the ASCII files were inspected for instances when two sensors were within transmission range of the subject's HeartWatch receiver. This occurred when two subjects passed each other within the effective transmission range of 42 inches. Additional off-scale readings can be attributed to strong electromagnetic interference such as radio or television antennae and high voltage power line surges. Such instances, characterized by an immediate but short-term doubling of heart rate, were deleted from the data set. The mean of each subject's heart rate for familiarization and for record firing was then calculated.

RESULTS

The principal results of this investigation are summarized in Figure 54 which shows the means and standard error of the means of the subjects' heart rates for both groups during familiarization firing during baseline day and during record firing on record-fire day. ANOVA procedures using the SYSTAT version 4.0 multiple general linear hypothesis module (Wilkinson, 1988) were implemented; the output is summarized in Table 5. The Groups effect revealed that heart rate was significantly elevated in the Competition Group compared to the Control Group ($F(1,10) = 17.771$, $p = .002$). The Days main effect indicated that heart rates were also significantly elevated during record fire ($F(1,10) = 44.767$, $p = .000$). Although Figure 54 suggests that the heart rate increment from familiarization firing to record firing was greater in the Competition Group than in the Control Group, the Days x Groups interaction was not significant ($F(1,10) = 3.773$, $p = .081$).

DISCUSSION

The present results suggest that the Competition Group was more autonomically aroused than the Control Group was when shooting during baseline and record-fire days. In addition, both groups displayed a heart rate increase of similar magnitude when moving from familiarization firing to record firing.

These findings suggest that heart rate has value as part of a physiological response profile, particularly when collected using unencumbering devices. The authors believe that heart rate data may, in this case, be a useful surrogate measure of anxiety. Exercise, which was held constant across both groups, did not contribute to the observed group differences.

The HeartWatches and their attendant computer interfaces and software proved to be quite serviceable. They yielded useful data while minimally encumbering the subjects. No failures were observed in this equipment. In this particular case, the utility of these heart rate data depended on the

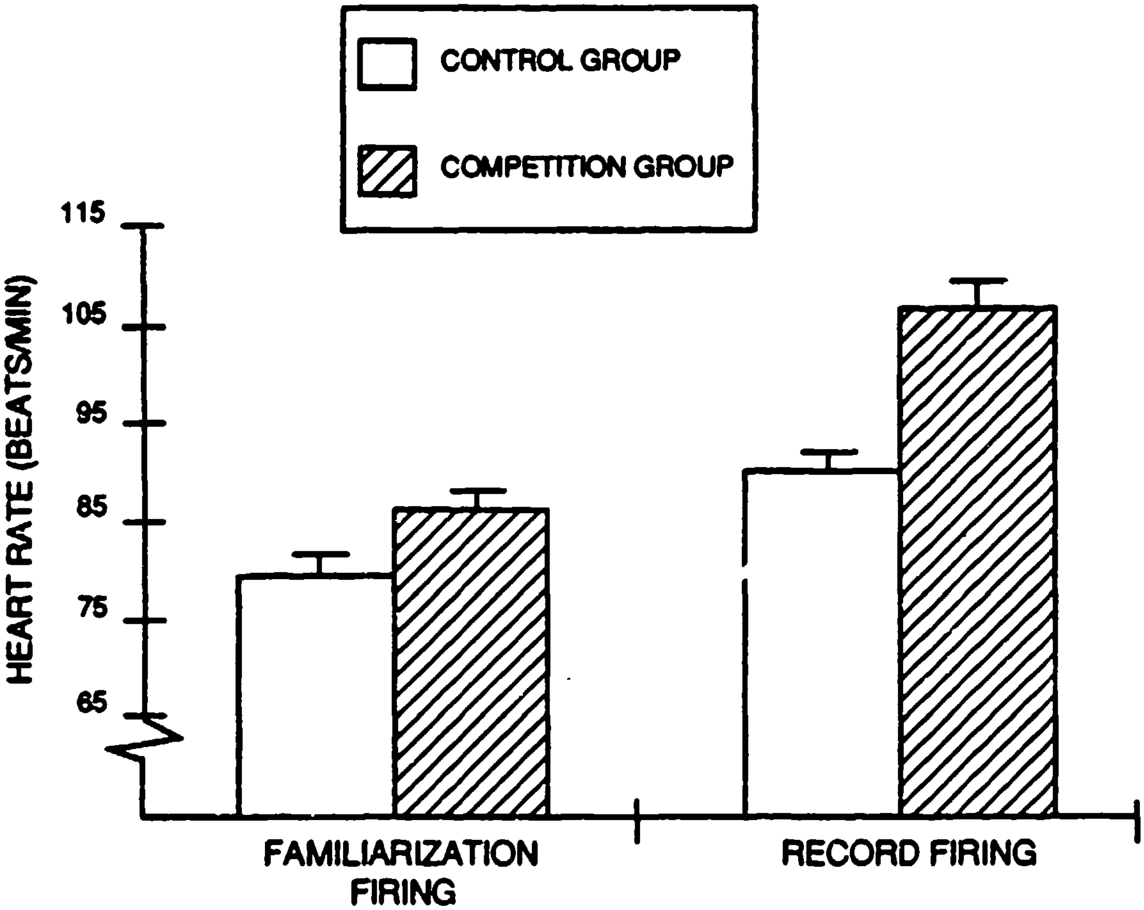


Figure 54. Mean (+standard error of the mean) of subjects' heart rates for the Control and Competition Groups during familiarization firing during baseline day and record-fire day.

Table 5

Analysis of Variance of Mean Heart Rates

Source	SS	df	MS	F	*p*
Total	3089.334	23			
Between	1204.334	11			
Groups	770.667	1	770.667	17.771	0.002
Error	433.667	10	43.367		
Within	1885.000	12			
Days	1441.500	1	1441.500	44.767	0.000
Days x Groups	121.500	1	121.500	3.773	0.081
Error	322.000	10	32.200		

Groups = Competition versus Control.
Days = Familiarization firing during baseline day versus record firing on record-fire day.

detailed records of each subject's activities which had been maintained while the heart rate was monitored, and on the detection of an apparent heart rate doubling or off scale (indicating that two subjects had come within transmitter range of each other) through visual inspections of the data.

The relationship between heart rate and performance, relatively well studied in competitive shooters (Wilkinson, Landers, and Daniels, 1981; Tretilova and Rodimkin, 1979; Landers, 1980; Yur'yev, 1980), should be investigated for less skilled groups. Further research in this area is planned.

In summary, this equipment proved to be excellent for making unobtrusive measurements of heart rate during field conditions. The heart rate data obtained proved to be a useful component of stress evaluation, particularly when collected with relatively unencumbering devices such as the HeartWatches.

CHAPTER 6

INTEGRATION OF PHYSIOLOGICAL, PSYCHOLOGICAL, AND PERFORMANCE FINDINGS

(J. M. King, G. A. Hudgens, S. Wansack, J. P. Torre, Jr.)

As was noted in Chapter 1 of this report, the present work was an attempt to expand HEL's stress research program, (Hudgens, Torre, Chatterton, Wansack, Fatkin, & DeLeon-Jones, 1986) by obtaining stress profiles for soldiers using individual equipment to accomplish military tasks when exposed to a real but non-injurious stressor, competition. This experiment is theoretically important for that reason. This study also provided data that will influence the ACR program by providing estimates of aiming error and hit probability for single round and burst modes of fire. This study also investigated a methodology for producing a known level of experimental stress in soldiers and applied HEL's preliminary stress metric to the task of measuring the stress levels produced. The stress was produced by having soldiers perform a military task, firing a rifle, in a competitive situation which reflected upon their unit and upon themselves. This was done in full view of their peers. The order of performance was not revealed. Other task-induced stressors included random presentation of targets by range, exposure time, and the number of targets available at a time.

STRESS EVALUATION

One of the primary objectives of this study was to determine if competition could be used to generate a significant level of stress in a systems test such as that included in this study. Accordingly, competition was included as a primary treatment variable, and other associated stress-promoting and readily standardized procedures (e.g., creating a meaningful reward contingency, having the individual perform before his teammates, etc.) were included as supporting components in this effort.

To determine whether a significant level of stress was generated in the study and to determine the relative degree of stress generated, batteries of psychological and physiological state measures were employed. Evaluations were made by reference to results obtained in a recent series of stress studies conducted as a part of the HEL stress program which used these same physiological and psychological state measures.

Results of the physiological evaluations were described in detail in Chapter 3. A comparison of the Competition and Control Groups indicated that the Competition Group showed consistently and significantly greater stress-related response changes for all five endocrine measures as a function of firing during competition than did the Control Group as a function of the same firing during noncompetitive conditions. Comparison of the endocrine data obtained for the Competition Group 15 minutes after firing for record in competition with the endocrine data obtained at the same relative time point in the Northwestern University stress protocols revealed that the Competition Group had a response profile very similar to that obtained for medical students when taking an important written examination, a moderately stressful situation. The Control Group, although showing some changes during time for some measures, generally had a profile more characteristic of other, relatively non-stressful, control conditions. Both groups in the present study differed considerably from all the other groups studied for the growth hormone measure. This effect may be accounted for by the greater physical activity involved in the present study as compared with the other studies, since growth hormone is extremely sensitive to changes in activity level. Both groups in the present study also showed relatively high levels of testosterone, even higher levels than the group of medical students taking an examination. At this time, the authors can only speculate that the relative level of testosterone observed across the groups might relate to differences in the performance requirements of the various situations. That is, testosterone production appears to have increased as the performance demands increased across the situations.

The psychological state data presented in Chapter 4 revealed response profiles for the Competition and Control Groups which strongly reinforce the conclusions reached based on the physiological state data. Consistent with the interpretation that the Competition Group was under more stress than the Control Group, the Competition Group subjects expressed significantly greater state anxiety than control subjects did both 15 minutes before, on the MAACL-R and after, on both the MAACL-R and the STAI, firing on record-fire day, and they rated the firing as significantly more stressful than did the control subjects on both the Subjective Stress Scale and the Subjective Rating of Events measures. Additionally, the Competition Group subjects expressed greater hostility and lower positive affect 15 minutes after firing. Both findings appear to reflect greater dissatisfaction with personal performance during competitive conditions.

The profiles of psychological data for the Competition and Control Groups compared with profiles for the Northwestern stress studies yielded results that were also very much like those for the physiological data. The anxiety expressed by the Competition Group appears most comparable to that of the group of medical students taking a written exam. This finding parallels the comparisons for the cortisol, prolactin, and luteinizing hormone data and supports the interpretation that a moderate level of stress was experienced by the Competition Group. Additionally, the comparative post-stress hostility ratings for the Competition and Control Groups reveal a pattern which is similar (across groups from the various studies) to the pattern of comparative testosterone levels. As was the case for testosterone, the magnitude of response appears to have increased as the performance demands increased across situations.

The heart rate data obtained from a limited subset of the subjects (see Chapter 5) also suggested that the competition was stressful. Since this measure has not been included in any of the other stress program studies, no comparative conclusions can be drawn at this time.

PERFORMANCE CORRELATES

Although this field experiment was initiated with two primary and separate objectives, namely, creating a method for generating stress in test situations and evaluating modes of fire to be used for the ACR field test, analyzing correlational relationships between the data obtained for the two purposes yielded much additional interesting information. For the purpose of analyzing these relationships, the marksmanship performance measures used were the numbers of targets hit in the semiautomatic and burst modes.

Two of the demographic measures taken were predictive of performance. The longer the soldiers reported being in the Army, the better they performed in the burst mode, and the greater the variety of weapons for which they were currently qualified, the better their performance in the semiautomatic mode.

Because of the time points at which the physiological and psychological measures were obtained, some of their relationships with performance can be considered predictive (those based on measures obtainad before record firing), while others can only be considered associative (those based on measures obtained after record firing). At the present time, these correlations between stress measures and performance are considered preliminary.

With regard to the hormone data, different predictive relationships appear to have existed depending on whether the subjects performed during competitive conditions. For the Control Group (no competition), lower prolactin levels early in the morning of baseline day and relatively higher prolactin levels early in the morning of record-fire day were predictive of better performance, particularly in the semiautomatic mode. For the Competition Group, lower testosterone levels on baseline day were predictive of better performance in the burst mode, and a relatively lower testosterone level early in the morning of record-fire day was predictive of better performance in the semiautomatic mode. Significant positive correlations were obtained for both groups between burst mode performance and change in testosterone level from baseline to record-fire day at the +15-minute time point. Better performers showed a smaller stress reaction, that is, suppression of testosterone, compared to those who did poorly.

Two personality (trait) measures were predictive of performance. Lower scores on both the MAACL-R Depression and Hostility Trait subscales were predictive of better performance. However, none of the state (stress perception) measures which were given on baseline day or before firing on record-fire day were predictive of performance.

Some of the psychological measures obtained after firing on record-fire day did, however, correlate significantly with performance. For instance, those Control Group subjects who reported using more avoidance behaviors in coping with whatever stress they were experiencing did not perform as well as those who did not tend to use that coping mechanism.

Two post-firing MAACL-R state measures correlated significantly with performance. Competition Group subjects who performed well reported higher Sensation Seeking scores that reflect higher levels of excitation (Zuckerman & Lubin, 1985). Control Group subjects who performed worse in the burst mode reported higher Hostility scores that reflect higher levels of frustration (Zuckerman & Lubin, 1985), presumably for not having done as well as they had expected.

This field experiment demonstrated that competition can be used to generate a moderate level of stress in the highly skilled and motivated soldier field experiment participants. Although the level of stress generated does not appear to have been sufficiently intense to have adversely affected the performance of the Competition Group relative to controls, this does not mean that the competition may not affect the performance of a direct fire weapon system. The Competition and Control Groups soldiers were from elite units and demonstrated the expected esprit de corps. They took pride in their performances and felt themselves under pressure to perform well. They realized they were involved in a group effort and that any poor individual score would penalize the entire team. As a result, the groups were competitive, and the psychological, endocrine and heart rate data indicated that they were stressed. The task of firing the M16A2 rifle may have been so straightforward that it was not affected by the level of stress induced, or the soldiers may have been sufficiently trained to be able to call upon their basic skills to overcome the performance effects otherwise induced by the competition stress.

An event that occurred after the record fire portions of this field experiment were completed emphasizes this point. The soldier with the highest score from a Competition Group was selected to fire a target scenario while being observed by a highly distinguished review panel. The soldier was so nervous that he had difficulty inserting the magazine into the weapon. The only words spoken by the soldier were "I know I can't do this." The safety officer, an experienced sergeant, leaned over and said "Son, just do what you did to get here; shoot like you know how." This soldier fired the highest score ever attained during any of the target presentation scenarios used in this experiment, and scored 30% higher than he had during the competition. This additional stress clearly altered his performance. Several aspects of combat stress are apparent in the pressure to perform, observation by officials, and play on self-esteem experienced by this soldier in this situation. A dramatic improvement in performance was observed in this case. Performance need not be degraded during stressful conditions. The soldier's training enabled him to respond to the stress with dramatically improved performance. While it is possible that the results of this field experiment would have been different if the soldiers who participated had been from less elite and highly trained units, individuals from such units, having lower expectations about their performance would have probably been less stressed.

It is also possible that the task-induced stressors of multiple targets, coupled with extremely short exposure times, may have been so severe as to override any differences attributable to the competition stress manipulation. In any event, rifle marksmanship performance, in the present experiment, was more affected by the task-induced stressors than by the competition stress.

Since future applications of a method for generating stress in systems evaluations will require a level of stress considered comparable to combat stress levels, research about methods of generating a higher level of stress will have to continue. The results of this study suggest that competition might serve as one component of a methodology which might also include multiple stressors or acute plus chronic stressors as combat stress appears to do. These findings also suggest that in evaluating a potentially stressful circumstance, it is important to consider both the objective (experimenter designated) and the subjective (subject experienced) aspects of the situation (Hobfoll, 1989).

SHOOTING PERFORMANCE

It is apparent from the data that virtually all of the improvement in hits attributable to burst mode in the present experiment was obtained at 50 meters. Also, any effects of multiple trigger pulls were largely confined to 50- and 100-meter ranges. Our failure to discover any substantial improvement in burst mode is consistent with AMSAA's analyses, (e.g., Fallin, 1969; Weaver, 1989), which have calculated that optimal performance would be obtained from systems in which the burst dispersion in mils is twice the aim error in mils. This work suggested that the relatively large three-round burst dispersion of the M16A2 equipped with the NWSC No. 1 muzzle device, 15.86 mils, would not yield any substantial improvement in combination with the relatively low aim errors observed in this experiment. Thus, the present results are consistent with AMSAA's analyses of the relationship between burst dispersion and aim error on one hand and optimal performance on the other.

THE NWSC NO. 1 MUZZLE DEVICE

The NWSC No. 1 muzzle device is currently among the most effective devices available for controlling burst dispersion in the M16A2 that does not induce reliability problems during required rates of sustained fire (Spadie, 1986), yet it does not approach the 8-mil dispersion that AMSAA feels is needed to improve burst performance. Thus, the level of improvement in hit probability displayed in burst mode is probably about the best currently obtainable with serial burst mode systems with a recoil impulse comparable to the M16A2. The present data suggest that the price of generalized use of burst mode, in terms of ammunition expended, may outweigh the increment in effectiveness when compared to semiautomatic mode for currently available serial burst systems.

CONCLUSIONS

This experiment (a) demonstrated that competition can be used to produce a moderate level of stress; (b) found that this moderate level of stress was insufficient to alter performance; (c) found that the tools and procedures of the preliminary stress metric are applicable to the assessment of stress levels in field experiments; (d) found that aim error is greater in burst mode than in semiautomatic mode, but the aim errors obtained were smaller than had been anticipated; (e) found that as predicted, a relatively high burst dispersion coupled with a relatively low aim error does not improve burst mode; and (f) helped define the limits of performance serial burst system with a recoil impulse comparable to the M16A2.

RECOMMENDATIONS

1. To establish firm links between stress and performance, future efforts in the HEL stress program should focus on higher stress situations than do those studied to date.

2. Based on the outcome of this field experiment, integration of basic and applied research efforts should be encouraged in the future.

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APPENDIX A

VOLUNTEER AGREEMENT AFFIDAVIT

VOLUNTEER AGREEMENT AFFIDAVIT

For use of this form, see AR 40-38; the proponent agency is the Office of the Surgeon General

THIS FORM IS AFFECTED BY THE PRIVACY ACT OF 1974

1. **AUTHORITY:** 10 USC 3012, 44 USC 3101 and 10 USC 1071-1087.

2. **PRINCIPAL PURPOSE:** To document voluntary participation in the Clinical Investigation and Research Program. SSN and home address will be used for identification and locating purpose.

3. **ROUTINE USES:** The SSN and home address will be used for identification and locating purposes. Information derived from the study will be used to document the study; implementation of medical programs; teaching; adjudication of claims; and for the mandatory reporting of medical condition as required by law. Information may be furnished to Federal, State and local agencies.

4. **MANDATORY OR VOLUNTARY DISCLOSURE:** The furnishing of SSN and home address is mandatory and necessary to provide identification and to contact you if future information indicates that your health may be adversely affected. Failure to provide the information may preclude your voluntary participation in this investigational study.

PART A - VOLUNTEER AFFIDAVIT

VOLUNTEER SUBJECTS IN APPROVED DEPARTMENT OF THE ARMY RESEARCH STUDIES

Volunteers under the provisions of AR 70-25 are authorized all necessary medical care for injury or disease which is the proximate result of their participation in such studies.

I, ______________________ (last, first, middle) SSN ______________________ having

full capacity to consent and having attained my ______ birthday, do hereby volunteer to participate in

The Salvo Stress Study
(research study)

under direction of James P. Torre/MAJ James King conducted at HEL, APG, MD 21005-5001 (name of institution)

The implications of my voluntary participation; the nature, duration and purpose of the research study; the methods and means by which it is to be conducted; and the inconveniences and hazards that may reasonably be expected have been explained to me by

MAJ James King

I have been given an opportunity to ask questions concerning this investigational study. Any such questions were answered to my full and complete satisfaction. Should any further questions arise concerning my rights on study-related injury I may contact

Patient Administration Branch, Kirk Army Clinic

at APG, MD (301) 278-2086
(name and address of hospital & phone number (include area code))

I understand that I may at any time during the course of this study revoke my consent and withdraw from the study without further penalty or loss of benefits however, I may be [X] required (military volunteer) or [ ] requested (civilian volunteer) to undergo certain examination if, in the opinion of the attending physician, such examinations are necessary for my health and well-being. My refusal to participate will involve no penalty or loss of benefits to which I am otherwise entitled.

PART B - TO BE COMPLETED BY INVESTIGATOR

INSTRUCTIONS FOR ELEMENTS OF INFORMED CONSENT: (Provide a detailed explanation in accordance with Appendix E, AR 40-38 or AR 70-25.)

1. I understand that the purpose of this research study is to determine ways in which stress reactions can be assessed in humans.

2. Mr. Torre or his designee has explained in detail all procedures and tests to be given to me. I understand the frequency, duration, and method of administration of all these as follows: One day prior to a record firing exercise a catheter (small plastic tube) from which blood samples will be drawn will be placed in my forearm. Small blood samples of 20 ml (1 oz.) will be drawn as described below. A total of 4 blood samples will be drawn over the course of 6 hours from the catheter. The catheter will then be withdrawn. This will be followed by a familiarization firing exercise. This sampling procedure will be repeated on the record fire day with 6 samples being taken. The total volume of blood drawn over 2 days will be approximately 200 ml (8 oz.).

(CONTINUE ON REVERSE)

3. I understand that the known risks, discomforts, and side effects that can be expected from the blood sampling are: Bruise at the site of vein puncture, inflammation of the vein and infection, and that care will be taken to avoid these complications. I understand that all information obtained in the investigation will be considered confidential. I understand that no information will be associated with me as a person and that my name will not appear in any published form in relation to the study.

4. I understand that I will be asked not to consume any caffeine-containing beverages (coffee, tea, colas) or alcohol from the time I arrive on Aberdeen Proving Ground until the last blood sample is drawn.

5. I understand that any injuries sustained as a result of participation in a research protocol are entitled to medical care and treatment.

6. I understand that the rifle firing portion of this study involves the use of an M16A2 rifle with a safety certified prototype muzzle brake. This firing involves no risks beyond those associated with normal marksmanship training.

7. I understand that I will be required to complete a number of surveys. There are no risks or hazards associated with them.

8. In addition to the other procedures described in this consent form, I agree to wear a heart rate detection strap and Heart Watch monitor during the periods of the test when blood samples are being collected on the baseline and record fire days. I understand that in wearing this electrode strap and Heart Watch monitor my heart rate will be recorded to provide additional physiological measures required by researchers in the conduct of this Salvo Stress Study. I understand that no more than 4 test participants per week will be asked to wear this device, and that declining to wear this device will not interfere with my participation in other aspects of this study.

9. I understand that I may be billeted on or off post for the course of the study, not to exceed 5 days.

10. I understand the benefits I may receive as a result of my taking part in this study are limited to additional practice with the M16 rifle. These studies will principally enhance the state of scientific knowledge.

SIGNATURE OF VOLUNTEER	DATE SIGNED	SIGNATURE OF LEGAL GUARDIAN (if volunteer is a minor)	
PERMANENT ADDRESS OF VOLUNTEER	TYPED OR PRINTED NAME AND SIGNATURE OF WITNESS		DATE SIGNED

Reverse of DA FORM 5303-R, APR 84

APPENDIX B

SAFETY CERTIFICATIONS FOR NWSC NO. 1 MUZZLE DEVICE

DEPARTMENT OF THE NAVY
NAVAL WEAPONS SUPPORT CENTER
CRANE, INDIANA 47522-5000

IN REPLY REFER TO:

8370/7
2021WS
2[illegible] JAN [illegible]

From: Commanding Officer, Naval Weapons Support Center
To: Director, Human Engineering Laboratory, (Mr. Sam Wansack), Aberdeen Proving Ground, Aberdeen, MD 21005-5001

Subj: SAFETY RELEASE JUSTIFICATION FOR THE NWSC #1 MUZZLE DEVICE USED ON THE M16A2 RIFLE

1. The following information is submitted by request of Mr. Wansack of your organization pursuant to requirements for testing of the NWSC #1 Muzzle Device which resulted from the Joint Services Small Arms Program FY 86 6.2 M16A2 Rifle Signature Suppression Project.

2. This device is constructed of heat treated 4140 alloy steel and there have been no safety or reliability problems encountered in any of the testing. Over 1000 rounds have been fired through one of the devices. The device is similar to the existing flash hider in size and external shape. It interfaces with the barrel/muzzle threads the same as the standard M16A2 flash hider, and is oriented in the same manner. The NWSC #1 muzzle device will allow mounting of the bayonet, and the standard blank firing device. It will launch grenades in the same manner as the standard M16A2 Flash Hider. Therefore, this device is judged to be as safe as the standard flash hider for the M16A2 rifle.

3. NAVWPNSUPPCEN Crane point of contact is Mr. William Spadie, Code 2021, Building 2521, telephone AV 482-3190/3191 or commercial 812-854-3190/3191, zip code 47522-5020.

Larry E Nash
[illegible] E. NASH
[illegible] tion

DEPARTMENT OF THE ARMY
HEADQUARTERS, U.S. ARMY TEST AND EVALUATION COMMAND
ABERDEEN PROVING GROUND, MARYLAND 21005-5055

REPLY TO ATTENTION OF

S: 25 Feb 88

AMSTE-TE-F (70-10p)

10 FEB 1988

MEMORANDUM FOR: Commander, U.S. Army Combat Systems Test Activity, ATTN: STECS-AS-LA

SUBJECT: Request for Safety Release of NWSC #1 Muzzle Device Used On the M16A2 Rifle

1. The U.S. Army Human Engineering Laboratory in memorandum, HEL, SLCHE-BR, 11 Feb 88, subject: Safety Release Justification for the NWSC#1 Muzzle Device Used For The M16A2 Rifle, enclosed, requests an analysis be performed to determine whether the muzzle device described in the attached letter can be granted a safety release.

2. The safety release is required for a field test to be performed by the Human Engineering Laboratory (HEL) beginning 29 Feb 88. The HEL point of contact, Mr. S. Wansack, x35969, has discussed this subject with Mr. F. Miller and shown him a sample of the device.

3. Request USACSTA provide a safety release recommendation for subject device by COB 25 Feb 88.

4. Point of contact, this headquarters, is Mr. Hubert M. Cole, AMSTE-TE-F, amstetef@apg-1.arpa, AUTOVON 298-3077/4784.

FOR THE COMMANDER:

signed

Encl

KEITH T. DIXON
Chief, FA, Inf & SW Div
Directorate for Test

CF:
Dir, USAHEL ATTN: SLCHE-BR (w/o encl)

APPENDIX C

DESCRIPTION OF M RANGE

DESCRIPTION OF M RANGE

M Range Capability

- FOUR FIRING LANES EACH 50 METERS WIDE--LANES CAN BE COMBINED TO INCREASE NUMBER OF TARGETS AND ANGLE FOR TWO GUNNERS OR ONE GUNNER.
- TARGET DISTANCES FROM 15 METERS TO 550 METERS.
- THREE TARGETS AT EACH RANGE FOR EACH FIRING LANE.
- ONE MOVING TARGET (33 FEET LONG) AT 80 METERS, 130 METERS, AND 180 METERS FOR EACH FIRING LANE AND WITH PRESET ADJUSTABLE VELOCITY.
- NON-INTRUSIVE SHOT DETECTOR AT EACH FIRING LANE.
- HIT DETECTOR AT EACH TARGET (WITH TARGET OPEN AND SHORT INDICATION).
- MISS DISTANCE INDICATOR CAPABILITY FOR ALL STATIONARY TARGETS TO 400 METERS OR WITHIN LIMITS DICTATED BY THE BULLET SHOCK WAVE.
- INDEPENDENT SCENARIO GENERATION FOR EACH FIRING LANE INCLUDING VARIABLE TARGET EXPOSURE TIME AND TIME BETWEEN TARGETS, AND SINGLE OR MULTIPLE TARGETS.

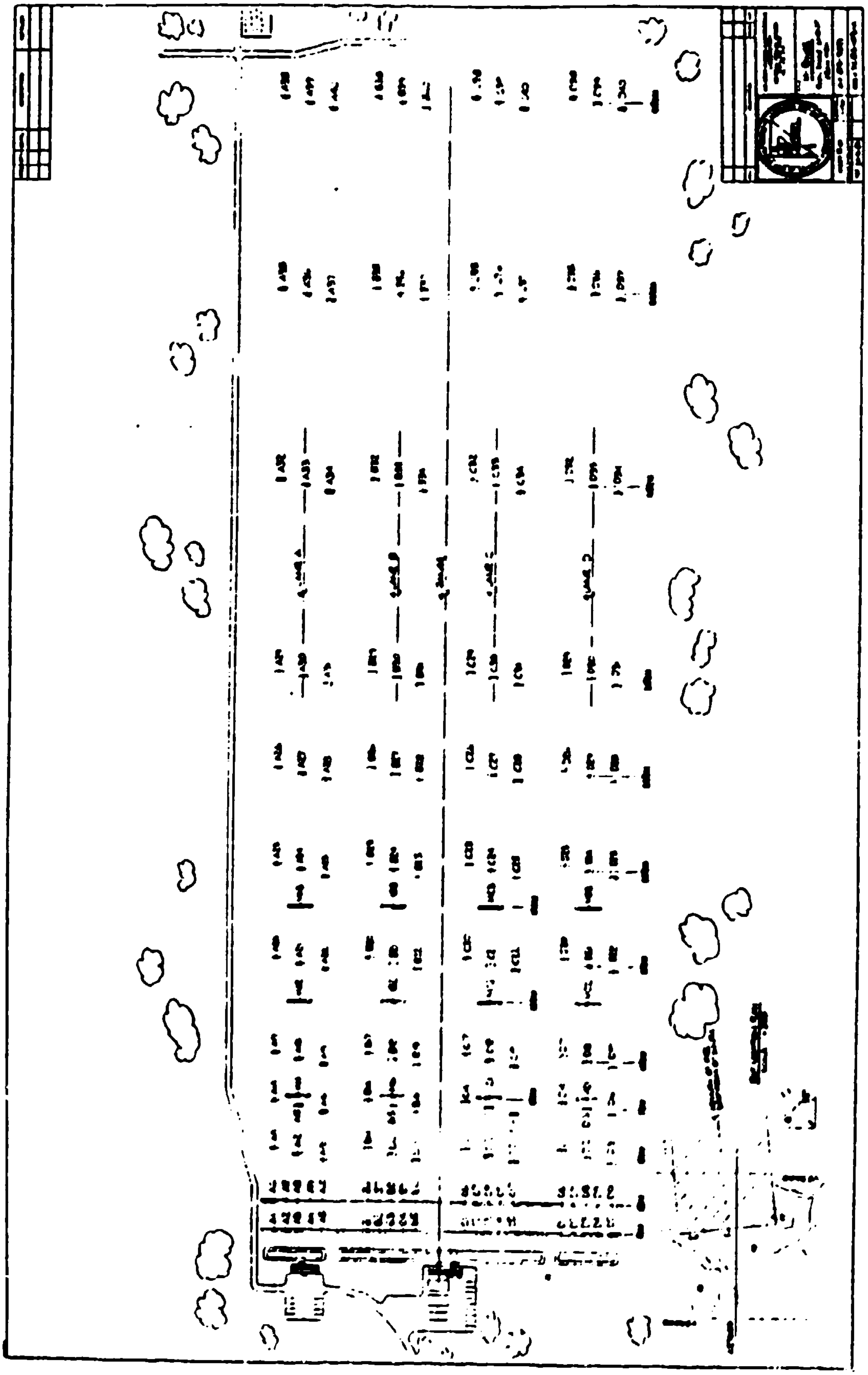


Figure C-1. Site plan for HEL's M Range. (Familiarization and record firing were conducted on Lane B.)

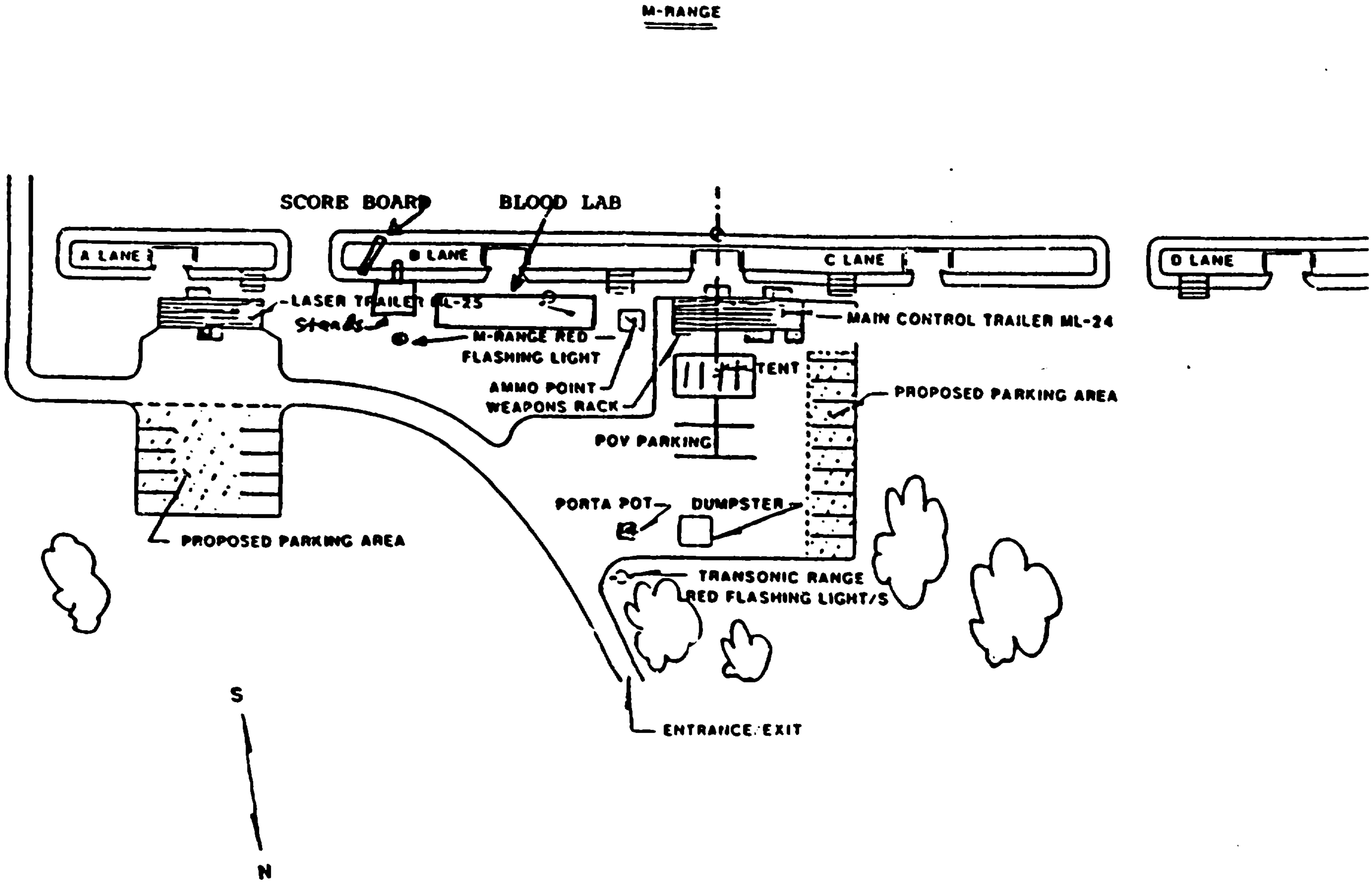


Figure C-2. Detail of the experimental area at HEL's M Range showing the location of the B Lane fox hole, the stands, the scoreboard, the blood sampling trailer, the tent where questionnaires were administered, the ammunition point, and the arms rack.

APPENDIX D

DOCUMENTATION OF ENDOCRINE SAMPLE ANALYSIS

DOCUMENTATION OF ENDOCRINE SAMPLE ANALYSIS

Assays were conducted in the Reproductive Endocrinology Laboratory, Department of Obstetrics and Gynecology, Northwestern Memorial Hospital. This laboratory is licensed by the State of Illinois as a clinical laboratory and participates in the College of American Pathologists quality control program. Cortisol, testosterone, prolactin, growth hormone, luteinizing hormone, epinephrine, norepinephrine, dopamine, B-endorphin and Met-enkephalin were measured.

Plasma was collected in EGTA, glutathione, and aprotinin and was rapidly frozen to prevent degradation of catecholamines and endogenous opiods.

CORTISOL

Serum samples were analyzed for cortisol by a direct assay without extraction (Casper, Chatterton, & Davis, 1979). Antiserum for this assay was obtained from Kew Scientific, Columbus, Ohio. It cross-reacts 0.01% with cortisone, 5% with corticcsterone, and 15% with deoxycortisol. Thus, it is suitable for use in human serum samples in which cortisol is present in much larger percentages than these other corticosteroids. Serum proteins were denatured by heating at 60° C for 30 minutes. ^{3}H-cortisol tracer and antiserum were then incubated with the cooled, diluted serum samples,, and unbound cortisol was removed by adding dextran-coated charcoal (DDC). The sensitivity of the assay (at the lowest range) is 17 nanograms (ng)/ml. The inter-assay coefficient of variation (CV) of the last 48 assays (midrange) was 27%. The intra-assay CV was 13%.

TESTOSTERONE

Serum samples were assayed for testosterone by a direct method without extraction. Materials including ^{125}I-testosterone for this procedure were obtained from Pantex. Antibody-bound testosterone is precipitated from solution by the addition of a second antibody in polyethylene glycol. The sensitivity of the assay (2 standard deviations [SD] at the lowest range) is 42 picograms (pg)/ml. The inter-assay CV of the last 50 assays (midrange) was 4%. Intra-assay CV was 5%.

PROLACTIN

Prolactin was measured in serum with materials obtained from the National Hormone and Pituitary Program for this assay. The standard and iodination materials were hPRL-I-6 and hPRL-RP-1, respectively. Iodination and radio-immuno-assay were conducted essentially as described by Hwang, Guyda, and Friesen (1971). The sensitivity of the assay based on 2 SDs of the lowest quality control preparation is 2.1 ng/ml. The inter-assay CV (midrange) in the 13 most recent assays was 10%. Intra-assay CV was 11%.

GROWTH HORMONE

Materials were obtained from the National Hormone and Pituitary Program for this assay. The standard and iodination materials were hGH-RP-1 and hGH-I-1, respectively. Iodination and radio-immuno-assay were also conducted as described by Hwang et al. (1971). The sensitivity of the assay based on 2 SDs of the lowest control preparation is 1.1 ng/ml. The inter-assay CV in the last 12 assays at a mean concentration of 4.2 ng/ml was 20%. Inter-assay CV was 6%.

LUTEINIZING HORMONE

Materials were supplied by the National Hormone and Pituitary Program. Iodination with ^{125}I, purification of the iodinated hormone, and separation of the antibody bound from unbound hormone was essentially as described by Midgley (1966) as modified by us (Judge, Quade, Arrata, & Chatterton, 1978). For hLH assay, the reference and iodination materials were LER-907 and hLH-I-3, respectively. Sensitivity for hLH and hFSH assays is 2.4 mIU/ml and 1.7 mIU/ml, respectively. The inter-assay CV (midrange) in the 34 most recent assays was 24%. Intra-assay CV was 11%.

CATECHOLAMINES

Analysis of epinephrine, norepinephrine, and dopamine was performed by means of reverse phase Waters high performance liquid chromatograph (HPLC) with electrochemical detection. Each of the catecholamines was separated during chromatography and quantified individually by an automated instrument (the HPLC), as described by Weicker, Feraudi, Hagele, and Pluto (1984).

B-ENDORPHIN (McIntosh, 1987)

Plasma was thawed and incubated overnight at 4° C with Sepharose bound anti-B-lipotropin antiserum to remove the B-LPH. This is necessary because the antiserum for radioimmunoassay (RIA) of B-endorphin binds B-LPH with similar affinity. Since B-LPH contains antigenic sites not common to B-endorphin, antisera that specifically bind B-LPH are available for this separation.

B-Endorphin was concentrated from 1.25 ml of B-LPH extracted serum by chromatography on octadecyl silica gel. The eluted B-endorphin was dried, reconstituted in assay buffer, and incubated with the B-endorphin antibody as the first step in the RIA. Antiserum is available that cross-reacts less than 0.1% with a-endorphin, dynorphin, Met-enkephalin, Leu-enkephalin, a-MSH, B-MSH, and gamma-MSH. To complete the assay, ^{125}I-endorphin was separated from that bound to the antibody by addition of a second antibody to form a precipitating complex. According to McIntosh (1987), recovery of B-endorphin through purification and assay procedure is 99%. The least detectable level in previous assays was 8.7 pg/ml with an interassay CV of 11.2%.

MET-ENKEPHALIN (Clement-Jones, Lowry, Rees, & Besser, 1980)

The enkaphalin also must be extracted from a relatively large volume of serum using the octadecyl silica gel chromatography step. However, the B-LDH does not have to be removed by specific antibody absorption. Met-enkaphalin is unstable, and it is therefore oxidized to its stable product Met-O-enkephalin with chloramine-T before being assayed. The assay employed a specific antiserum from Chemicon InH and a ^{125}I-iodinated pure Met-O-enkephalin tracer. Bound and free peptides were separated by adding a second antibody.

SAMPLE HANDLING AND DATA PROCESSING

When the samples were received in the RIA lab, they were put in a freezer and the sample numbers, which are assigned consecutively in each Project, were entered (logged) in the computer with information about the project number, data, assay to be performed and number of tubes. The data file for each project kept a running total of samples assayed. This was updated and printed weekly.

The Work List, which was composed of samples for a given assay, was printed each day an assay was to be done. Results were entered in the Work List at the completion of the assay. The data from each project was then transferred internally to the existing data files for the project under the specific hormone assayed. The files have a place for date, time, subject, group, and so forth, which the investigator can enter for each sample number either before or after the assay values are entered.

When the Work List was completed, the assay was conducted by the procedures described. All assays were quantified by counting labeled hormone that remains bound to the antiserum. The amount of radioactivity bound is inversely related to the amount of hormone in the sample. An on-line computer plotted the bound radioactivity versus the concentration of standards in a logit-log format after subtracting nonspecific binding. Concentrations of hormone in the samples were then calculated automatically from the standard curve. The following quality control data were included within the updated Work List for the hard copy file kept in the laboratory.

Values of 3 QCs
Mean values from all previous assays of these QCs
Nonspecific binding
Slope of logit-log plot
Correlation coefficient (standard curve)
Percent of tracer bound
Range of standards
Value at 50% binding

References

Casper, R. C., Chatterton, R. T. Jr., & Davis, J. M. (1979). Alterations in serum cortisol and its binding characteristics in anorexia nervosa. Journal of Clinical Endocrinology and Metabolism, 49, 406-411.

Clement-Jones, V., Lowry, P. J., Rees, L. H., & Besser, G. M. (1980). Development of a specified extracted radioimmunoassay for methionine enkephalin in human plasma and cerebrospinal fluid. Journal of Endocrinology, 86, 231-243.

Hwang, P., Guyda, H., & Friesen, H. (1971). A radioimmunoassay for human prolactin. Proceedings of the National Academy of Science, 68, 1902-1906.

Judge, S. M., Quade, J. P., Arrata, W. S. M., & Chatterton, R. T. Jr. (1978). Time course relationships between serum LH, serum progesterone, and urinary pregnanediol concentrations in normal women. Steroids, 31, 175-187.

McIntosh, T. K. (1987). Prolonged disruption of plasma B-endorphin dynamics after trauma in the non-human primate. Endocrinology, 120, 1734-1744.

Midgley, A. R. Jr. (1966). Radioimmunoassay: A method for human chorionic gonadotropin and human luteinizing hormone. Endocrinology, 79, 10-18.

Weicker, H., Feraudi, M., Hagele, H., & Pluto, R. (1984). Electrochemical detection of catecholamines in urine and plasma after separation with HPLC. Clinica Chimica Acta, 141, 17-25.

APPENDIX E

SURVEYS AND DATA COLLECTION FORMS

GENERAL INFORMATION QUESTIONNAIRE

Please answer all questions as completely as possible by filling in the blanks or circling the appropriate response. All information will be kept strictly confidential. The information is important for test purposes and will not be used for any other purpose.

1. NAME ____________________ 2. DATE OF BIRTH ________________

3. PRIMARY MOS ______________ 4. PRESENT PAY GRADE E-__________

5. LENGTH OF SERVICE _____ (years) _____ (months) 6. EDUCATION LEVEL ___________

7. WHAT IS YOUR UNIT? ________ PLATOON ________ DIVISION
________ COMPANY ________ BRIGADE
________ BATTALION

8. HOW LONG HAVE YOU BEEN IN YOUR PRESENT SQUAD? _______ (years) _______ (months)

9. DO YOU HAVE A PHYSICAL PROFILE AT THIS TIME? _____ yes _____ no

10. DURING THE PAST WEEK, HAVE YOU TAKEN ANY PRESCRIPTION OR NON-PRESCRIPTION DRUGS? YES _____ NO _____
IF YES, WHAT KIND(S)?
1.________________________ DATES:______________
2.________________________ DATES:______________
3.________________________ DATES:______________
4.________________________ DATES:______________

11. LIST YOUR CURRENT WEAPONS QUALIFICATIONS:

1.______________________________
2.______________________________
3.______________________________
4.______________________________
5.______________________________

12. WHAT WAS YOUR WEAPONS QUALIFICATION ON YOUR LAST RECORD FIRE? (EXPERT, MARKSMAN, OR SHARP SHOOTER) ______________________

13. HOW MANY ROUNDS HAVE YOU FIRED? (IN YOUR ENTIRE LIFE) ________________

14. HAVE YOU BEEN TO SNIPER SCHOOL? YES ______ NO ______

15. HAVE YOU HAD ANY FORMAL SMALL ARMS TRAINING? (PARTICIPATED IN MATCHES, MEMBER OF A RIFLE TEAM, ETC.)? YES ______ NO ______

IF YES, LIST BELOW:

1. ________________________ DATE ______________
2. ________________________ DATE ______________
3. ________________________ DATE ______________
4. ________________________ DATE ______________

LIFE EVENTS FORM I

1. Check the appropriate response: "I have recently experienced:"

   Unusually low stress ____
   Mild stress ____
   Moderate stress ____
   High stress ____
   Unusually high stress ____

2. Have you recently experienced any events having an impact on your life?
   Yes ___ No ___
   Please list them and indicate them as positive or negative by placing them in the corresponding column:

POSITIVE	DATE EVENTS OCCURED

NEGATIVE	DATE EVENTS OCCURED

3. "Overall, my response to the above events was to feel:" (Please circle the number under each of the four headings listed below that reflects the degree that you felt that emotion.)

HARMED

1 2 3 4 5
Not at all ... Very much

THREATENED

1 2 3 4 5
Not at all ... Very much

CHALLENGED

1 2 3 4 5
Not at all ... very much

SUCCESSFUL

1 2 3 4 5
Not at all ... Very much

4. How would you rate the way you handled these stresses?

Very well ______
Well ______
Not well ______
Adequate ______
Poorly ______

5. "My resources for responding to the events were:"

More than adequate ______
Adequate ______
Less than adequate ______

Thank you

LIFE EVENTS FORM II

1. Check the appropriate response: "In the last 24 hours, I have experienced:"

   Unusually low stress ______
   Mild stress ______
   Moderate stress ______
   High stress ______
   Unusually high stress ______

2. Have you experienced any events having an impact on your life in the last 24 hours? Yes ______ No ______
   Please list them and indicate them as positive or negative by placing them in the corresponding column, noting exactly when each event occurred:

POSITIVE	EVENT OCCURRED (Date and Time)

NEGATIVE	EVENT OCCURRED (Date and Time)

3. "Overall, my response to the above events was to feel:" (Please circle the number under each of the four headings listed below that reflects the degree that you felt under that emotion.)

HARMED

1	2	3	4	5
Not at all				Very much

THREATENED

1	2	3	4	5
Not at all				Very much

CHALLENGED

1	2	3	4	5
Not at all				Very much

SUCCESSFUL

1	2	3	4	5
Not at all				Very much

4. How would you rate the way you handled these stresses?

Very well ______
Well ______
Not well ______
Adequate ______
Poorly ______

5. "My resources for responding to the events were:"

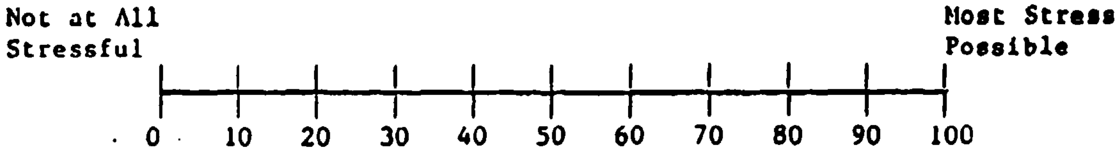
More than adequate ______
Adequate ______
Less than adequate ______

Thank you

Rating of Events - Specific

1. The scale below represents a range of how stressful an event might be. Put a check mark touching the line (✓) to rate how much stress you have experienced during the last half hour.

STRESS SCALE



2. At what number value does the check mark touch the line? ________

Rating of Events - Specific

1. The scale below represents a range of how stressful an event might be. Put a check mark touching the line (✓) to indicate where you rate the experience of today's weapon firing competition.

STRESS SCALE

2. At what number value does the check mark touch the line? _______

Rating of Events - Specific

1. The scale below represents a range of how stressful an event might be. Put a check mark touching the line (√) to indicate where you rate the experience of today's weapon firing comparison.

STRESS SCALE

Not at All Stressful — Most Stress Possible

0 10 20 30 40 50 60 70 80 90 100

2. At what number value does the check mark touch the line? ________

Rating of Events - General

1. What was the most stressful event in your life before today?

____

____

____

2. The scale below represents a range of how stressful an event might be. Put a check mark touching the line (√) to indicate where you rate the most stressful event (from question #1).

STRESS SCALE

Not at All Stressful — Most Stress Possible

0 10 20 30 40 50 60 70 80 90 100

3. At what number value does the check mark touch the line? ________

4. Compared to the rating you gave in item 3 for the most stressful event, what number rating would you give the stress you experienced as a result of today's weapon firing competition? ________

Rating of Events - General

1. What was the most stressful event in your life before today?

____

____

____

2. The scale below represents a range of how stressful an event might be. Put a check mark touching the line (√) to indicate where you rate the most stressful event (from question #1).

STRESS SCALE

Not at All Stressful — Most Stress Possible

0 10 20 30 40 50 60 70 80 90 100

3. At what number value does the check mark touch the line? ________

4. Compared to the rating you gave in item 3 for the most stressful event, what number rating would you give the stress you experienced as a result of today's weapon firing comparison?________

SSE

1. ON A SCALE FROM 1 TO 10, HOW CONFIDENT ARE YOU IN YOUR ABILITY TO DEAL WITH THE TODAY'S EXPERIENCES? PLEASE CIRCLE ONE OF THE NUMBERS BELOW.

1 2 3 4 5 6 7 8 9 10

Not at all confident — Extremely confident

SSE

1. ON A SCALE FROM 1 TO 10, HOW CONFIDENT ARE YOU IN YOUR ABILITY TO DEAL WITH THE STRESS OF THE WEAPON FIRING COMPETITION? PLEASE CIRCLE ONE OF THE NUMBERS BELOW.

1 2 3 4 5 6 7 8 9 10

Not at all confident | Extremely confident

SSE

1. ON A SCALE FROM 1 TO 10, HOW CONFIDENT ARE YOU IN YOUR ABILITY TO DEAL WITH THE WEAPON FIRING COMPARISON? PLEASE CIRCLE ONE OF THE NUMBERS BELOW.

1	2	3	4	5	6	7	8	9	10
Not at all confident									Extremely confident

END-OF-STUDY SURVEY

CIRCLE THE NUMBER THAT CORRESPONDS TO YOUR ANSWER:

1. AT YOUR UNIT, HOW OFTEN DO YOU FIRE A MILITARY RIFLE IN SEMI-AUTOMATIC MODE?

1	2	3	4	5
ONCE A WEEK	SEVERAL TIMES A MONTH	ONCE A MONTH	SEVERAL TIMES A YEAR	ONCE A YEAR

2. AT YOUR UNIT, HOW OFTEN DO YOU FIRE A RIFLE IN BURST OR FULL-AUTOMATIC MODE?

1	2	3	4	5
ONCE A WEEK	SEVERAL TIMES A MONTH	ONCE A MONTH	SEVERAL TIMES A YEAR	ONCE A YEAR

3. HOW EFFECTIVE WAS THE MUZZLE BRAKE INSTALLED ON THE RIFLES USED IN THIS STUDY IN CONTROLLING MUZZLE CLIMB IN BURST MODE?

1	2	3	4	5
NOT AT ALL EFFECTIVE				EXTREMELY EFFECTIVE

4. DID THE MUZZLE BRAKE INSTALLED ON THE RIFLES USED IN THIS STUDY ALTER THE RIFLES PERFORMANCE?

1	2	3	4	5
SEVERELY DEGRADED PERFORMANCE		NO CHANGE		GREATLY ENHANCED PERFORMANCE

5. WOULD YOU LIKE TO HAVE THE TYPE OF MUZZLE BRAKE USED IN THIS STUDY INSTALLED ON YOUR INDIVIDUAL WEAPON?

1	2	3	4	5
NO		MAKES NO DIFFERENCE		YES

6. PLEASE NOTE ANY OTHER COMMENTS ABOUT THE MUZZLE BRAKES, SIGHTS, OR OTHER RIFLE-RELATED EQUIPMENT:

7. WHICH MODE DO YOU THINK IS BETTER TO FIRE: (check one)

_______ SEMI-AUTOMATIC
_______ BURST

8. PLEASE INDICATE HOW STRESSFUL YOU FOUND THE PORTIONS OF THE STUDY LISTED BELOW TO BE:

	1 NOT AT ALL STRESSFUL	2	3	4	5 HIGHLY STRESSFUL
ZEROING	1	2	3	4	5
FAMILIARIZATION FIRING	1	2	3	4	5
QUESTIONNAIRES	1	2	3	4	5
CATHETER INSERTION	1	2	3	4	5
WEARING CATHETER	1	2	3	4	5
BLOOD SAMPLING	1	2	3	4	5
CATHETER REMOVAL	1	2	3	4	5
RECORD FIRING	1	2	3	4	5
TRAVEL TO/FROM APG	1	2	3	4	5

9. PLEASE NOTE ANY OTHER COMMENTS ABOUT THE STUDY OR ABOUT YOUR TDY AT APG:

APPENDIX F

METEOROLOGICAL MEASUREMENTS

METEOROLOGICAL MEASUREMENTS

Date	Time	Temp (F)	Wind speed (knots)	Wind direction (degrees)	Visibility (miles)
09 Mar 88	0900	45	03	230	3
	1200	54	09	210	3
	1500	59	16G20	200	7
10 Mar 88	0900	45	10G19	350	7
	1200	49	13G21	340	7
	1500	50	17G25	330	7
11 Mar 88	0900	42	06	340	7
	1200	48	07	310	7
	1500	52	08	210	7
16 Mar 88	0900	35	13G20	330	7
	1200	46	10G24	340	7
	1500	45	17G25	340	7
17 Mar 88	0900	37	10G17	330	7
	1200	41	14	340	7
	1500	48	14G23	330	7
18 Mar 88	0900	38	03	260	7
	1200	42	10	240	7
	1500	41	10G17	250	7
22 Mar 88	0900	27	05	020	7
	1200	38	06	030	7
	1500	40	05	160	7
23 Mar 88	0900	43	05	200	6
	1200	52	10	210	7
	1500	57	13G19	190	7
24 Mar 88	0900	58	12	210	6
	1200	67	10	210	7
	1500	72	10G14	190	7

APPENDIX G

SCHEDULES

SCHEDULES

Weekly Schedule for Salvo Stress Study

Schedule Abbreviations

B1 to B6	Blood samples 1 to 4 on baseline day, 1 to 6 on record-fire day
()	Firing, baseline day
FR	Firing, record-fire day
IC	Insert catheter
OR	Overall rating of events
RC	Remove catheter
SP	Stress perception measures (state)

Monday

0830-1500	Travel
1500-1630	Inprocess, Briefing, Psychological surveys, IDs
1630-1900	Dinner

Tuesday

0555	Bus from billet to dining facility
0600-0620	Breakfast
0620-0700	Bus to range
0700-0800	Psychological surveys
0800-1000	Burst mode instruction
1000-1130	Zeroing weapons (HR)
1130-1230	Lunch
1230-1600	Zeroing weapons, Familiarization at 50, 100m
1600-1640	Bus to billet
1730-1800	Dinner

Wednesday

0555	Bus from billet to dining facility
0600-0620	Breakfast
0620-0700	Bus to range
0700-0815	Insert catheters
0730-1300	Baseline blood samples (4 in 2.25 hours) HR
0920-1255	Psychological surveys (10 minutes each)
0955-1305	Remove catheters
1100-1330	Lunch
1020-1700	Familiarization firing at 200, 300m
1700-1740	Bus to billet
1800-1900	Dinner

Thursday

0555	Bus from billet to dining facility
0600-0620	Breakfast
0620-0700	Bus to range
0700-0815	Insert catheters
0730-1445	Test blood samples (6 in 4 hr, 3 pre, 3 post) HR
0920-1235	Pre firing psychological survey (10 minutes each)
0930-1245	Record firing (15 minutes each, 144 targets)
0945-1255	Post firing psychological survey (10 minutes ea.)
1140-1450	Remove catheters
1150-1500	Lunch
1235-1545	Ending psychological measures (5 minutes each)

1600-1630	OuSubjectrocessing from field experiment
1630-1720	Bus to billet
1800-1900	Dinner

Friday Travel Day

0615	Bus to dining facility
0620-0700	Breakfast
0700-0745	Clear billet, Bus to range (as needed)
0830-1200	Make up firing (as needed)
1200	Depart APG

Baseline Day Schedule (Wednesday)

S No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
NURSE	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	
0700	IC	IC	IC																		0700
0705	IC	IC	IC																		0705
0710				IC	IC	IC															0710
0715				IC	IC	IC															0715
0720							IC	IC	IC												0720
0725							IC	IC	IC												0725
0730	B1										IC	IC									0730
0735											IC	IC									0735
0740										IC					IC						0740
0745		B1								IC					IC						0745
0750													IC	IC				IC			0750
0755													IC	IC				IC			0755
0800	B2		B1														IC				0800
0805																	IC				0805
0810																					0810
0815		B2		B1																	0815
0820																IC				IC	0820
0825																IC				IC	0825
0830			B2		B1														IC		0830
0835																			IC		0835
0840																					0840
0845	B3			B2		B1															0845
0850	SP																				0850
0855																					0855
0900	()	B3			B2		B1														0900
0905	()	SP																			0905
0910	()																				0910
0915		()	B3			B2		B1													0915
0920	SP	()	SP																		0920
0925		()																			0925
0930	B4		()	B3			B2		B1												0930
0935		SP	()	SP																	0935
0940	RC		()																		0940
0945		B4		()	B3			B2		B1											0945
0950			SP	()	SP																0950
0955		RC		()																	0955
1000			B4		()	B3			B2		B1										1000
1005				SP	()	SP															1005
1010			RC		()																1010
1015				B4		()	B3			B2		B1									1015
1020					SP	()	SP														1020
1025				RC		()															1025
1030							()	B3			B2		B1								1030
1035					B4	SP	()	SP													1035
1040							()														1040
1045					RC	B4		()	B3			B2		B1							1045
1050							SP	()	SP												1050
1055						RC		()													1055
1100							B4		()	B3			B2		B1						1100
1105								SP	()	SP											1105
1110							RC		()												1110
1115								B4		()	B3			B2		B1					1115

S No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
1120									SP	()	SP										1120
1125								RC		()											1125
1130									B4		()	B3			B2		B1				1130
1135										SP	()	SP									1135
1140									RC		()										1140
1145										B4		()	B3			B2		B1			1145
1150											SP	()	SP								1150
1155										RC		()									1155
1200											B4		()	B3			B2		B1		1200
1205												SP	()	SP							1205
1210											RC		()								1210
1215												B4		()	B3			B2		B1	1215
1220													SP	()	SP						1220
1225												RC		()							1225
1230													B4		()	B3			B2		1230
1235														SP	()	SP					1235
1240													RC		()						1240
1245														B4		()	B3			B2	1245
1250															SP	()	SP				1250
1255														RC		()					1255
1300															B4		()	B3			1300
1305																SP	()	SP			1305
1310															RC		()				1310
1315																B4		()	B3		1315
1320																	SP	()	SP		1320
1325																RC		()			1325
1330																	B4		()	B3	1330
1335																		SP	()	SP	1335
1340																	RC		()		1340
1345																		B4		()	1345
1350																		RC	SP	()	1350
1355																				()	1355
1400																			B4		1400
1405																			RC	SP	1405
1410																					1410
1415																				B4	1415
1420																				RC	1420
1425																					1425
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1550																					1550
1555																					1555
1600																					1600

Record-Fire Day Schedule (Thurdsay)

S No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
NURSE	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	
0700	IC	IC	IC																		0700
0705	IC	IC	IC																		0705
0710				IC	IC	IC															0710
0715				IC	IC	IC															0715
0720							IC	IC	IC												0720
0725							IC	IC	IC												0725
0730	B1										IC	IC									0730
0735											IC	IC									0735
0740										IC					IC						0740
0745		B1								IC					IC						0745
0750													IC	IC				IC			0750
0755													IC	IC				IC			0755
0800	B2		B1														IC				0800
0805																	IC				0805
0810																					0810
0815		B2		B1																	0815
0820																IC				IC	0820
0825																IC				IC	0825
0830			B2		B1														IC		0830
0835																			IC		0835
0840																					0840
0845	B3			B2		B1															0845
0850	SP																				0850
0855																					0855
0900	FR	B3			B2		B1														0900
0905	FR	SP																			0905
0910	FR																				0910
0915		FR	B3			B2		B1													0915
0920	SP	FR	SP																		0920
0925		FR																			0925
0930	B4		FR	B3			B2		B1												0930
0935		SP	FR	SP																	0935
0940			FR																		0940
0945		B4		FR	B3			B2		B1											0945
0950			SP	FR	SP																0950
0955				FR																	0955
1000			B4		FR	B3			B2		B1										1000
1005				SP	FR	SP															1005
1010					FR																1010
1015	B5			B4		FR	B3			B2		B1									1015
1020					SP	FR	SP														1020
1025						FR															1025
1030		B5			B4		FR	B3			B2		B1								1030
1035						SP	FR	SP													1035
1040							FR														1040
1045			B5			B4		FR	B3			B2		B1							1045
1050							SP	FR	SP												1050
1055								FR													1055
1100				B5			B4		FR	B3			B2		B1						1100
1105								SP	FR	SP											1105
1110									FR												1110
1115	B6				B5			B4		FR	B3			B2		B1					1115

S No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
1120									SP	FR	SP										1120
1125	RC									FR											1125
1130		B6				B5			B4		FR	B3			B2		B1				1130
1135										SP	FR	SP									1135
1140		RC									FR										1140
1145	OR		B6				B5			B4		FR	B3			B2		B1			1145
1150											SP	FR	SP								1150
1155			RC									FR									1155
1200		OR		B6				B5			B4		FR	B3			B2		B1		1200
1205												SP	FR	SP							1205
1210				RC									FR								1210
1215			OR		B6				B5			B4		FR	B3			B2		B1	1215
1220													SP	FR	SP						1220
1225					RC									FR							1225
1230				OR		B6				B5			B4		FR	B3			B2		1230
1235														SP	FR	SP					1235
1240						RC									FR						1240
1245					OR		B6				B5			B4		FR	B3			B2	1245
1250															SP	FR	SP				1250
1255							RC									FR					1255
1300						OR		B6				B5			B4		FR	B3			1300
1305																SP	FR	SP			1305
1310								RC									FR				1310
1315							OR		B6				B5			B4		FR	B3		1315
1320																	SP	FR	SP		1320
1325									RC									FR			1325
1330								OR		B6				B5			B4		FR	B3	1330
1335																		SP	FR	SP	1335
1340										RC									FR		1340
1345									OR		B6				B5			B4		FR	1345
1350											RC								SP	FR	1350
1355																				FR	1355
1400										OR		B6				B5			B4		1400
1405												RC								SP	1405
1410																					1410
1415											OR		B6				B5			B4	1415
1420													RC								1420
1425																					1425
1430												OR		B6				B5			1430
1435														RC							1435
1440																					1440
1445													OR		B6				B5		1445
1450															RC						1450
1455																					1455
1500														OR		B6				B5	1500
1505																RC					1505
1510																					1510
1515															OR		B6				1515
1520																	RC				1520
1525																					1525
1530																OR		B6			1530
1535																		RC			1535
1540																					1540
1545																	OR		B6		1545
1550																			RC		1550
1555																					1555

S No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
1600																		OR		B6	1600
1605																				RC	1605
1610																					1610
1615																			OR		1615
1620																					1620
1625																					1625
1630																				OR	1630

APPENDIX H

SCENARIO SEQUENCE LISTINGS

SCENARIO SEQUENCE LISTINGS

Sequence Pair Selection for Subjects

		SECOND					
		1	2	3	4	5	6
	1	X	20	22	3	14	29
F	2	16	X	27	11	17	25
I R	3	6	13	X	26	18	19
S T	4	9	1	23	X	24	7
	5	30	8	28	15	X	2
	6	4	10	21	12	5	X

FIRST and SECOND refer respectively to the first and second sequence to be fired by a subject. For all subjects, odd numbered subjects fired semiautomatic mode first while even numbered subjects fired burst mode first. Each subject was randomnly associated with a random number from 1 to 30, with each number representing a unique non-repeating pairing of sequences. The element of the matrix above containing that number was then located, and that subject was assigned the sequences indicated on the top and left side of the matrix. The pairings associated with each subject are also given in this appendix. The sequences themselves were six random sequences of the 36 possible target events. They are listed following the sequence parings.

Sequence Pairs for All Subjects

Pairing	Competition subject	Control subject
3	1	21
1	2	22
6	3	23
11	4	24
25	5	25
10	6	26
28	7	27
16	8	28
4	9	29
22	10	30
20	11	31
26	12	32
24	13	33
5	14	34
18	15	35
23	16	36
13	17	37
21	18	38
15	19	39
8	20	40
2	41	
7	42	
30	43	
14	44	
9	45	
12	46	
27	47	
17	48	
29	49	
19	50	
20	51	
22	52	
3	53	
14	54	
29	55	
16	56	
27	57	
11	58	
17	59	
25	60	

Sequence 1

Target sequence No.	Number of targets	Range (meters)	Time up (seconds)	Delay (seconds)
1	1	200	5.0	3
2	3	200	5.0	3
3	2	200	5.0	4
4	3	50	5.0	3
5	1	100	3.0	3
6	1	300	3.0	4
7	3	200	3.0	5
8	2	100	3.0	5
9	1	200	1.5	4
10	3	300	3.0	5
11	3	50	1.5	3
12	2	50	3.0	5
13	3	300	1.5	3
14	2	200	1.5	5
15	2	200	3.0	5
16	3	300	5.0	5
17	2	300	1.5	4
18	1	200	3.0	3
19	1	300	1.5	4
20	1	300	5.0	4
21	3	200	1.5	3
22	3	100	1.5	4
23	3	50	3.0	5
24	2	300	5.0	5
25	2	100	1.5	4
26	2	50	1.5	5
27	2	50	5.0	4
28	2	[illegible]	3.0	3
29	1	100	5.0	4
30	1	50	1.5	3
31	1	100	1.5	5
32	1	50	5.0	4
33	2	100	5.0	5
34	3	100	5.0	3
35	1	50	3.0	4
36	3	100	3.0	3

Sequence 2

Target sequence No.	Number of targets	Range (meters)	Time up (seconds)	Delay (seconds)
1	2	50	5.0	4
2	2	200	3.0	5
3	2	300	1.5	4
4	3	50	3.0	5
5	2	200	5.0	4
6	1	200	1.5	4
7	1	50	5.0	4
8	3	200	1.5	3
9	1	100	5.0	4
10	3	100	5.0	3
11	2	50	1.5	5
12	1	200	3.0	3
13	3	300	1.5	3
14	1	300	3.0	4
15	2	100	1.5	4
16	2	300	5.0	5
17	2	300	3.0	3
18	1	100	3.0	3
19	3	300	3.0	5
20	3	200	3.0	5
21	2	50	3.0	5
22	2	100	5.0	5
23	2	200	1.5	5
24	3	50	1.5	3
25	1	50	3.0	4
26	3	50	5.0	3
27	1	200	5.0	3
28	3	100	1.5	4
29	3	100	3.0	3
30	1	300	5.0	4
31	3	300	5.0	5
32	2	100	3.0	5
33	1	300	1.5	4
34	1	100	1.5	5
35	3	200	5.0	3
36	1	50	1.5	3

Sequence 3

Target sequence No.	Number of targets	Range (meters)	Time up (seconds)	Delay (seconds)
1	3	300	3.0	5
2	2	200	5.0	4
3	2	300	1.5	4
4	2	200	3.0	5
5	3	50	1.5	3
6	1	300	5.0	4
7	2	50	3.0	5
8	3	300	1.5	3
9	1	200	5.0	3
10	1	300	1.5	4
11	3	200	3.0	5
12	3	100	5.0	3
13	1	50	1.5	3
14	1	100	1.5	5
15	3	100	1.5	4
16	1	200	3.0	3
17	2	300	3.0	3
18	3	200	1.5	3
19	1	50	3.0	4
20	1	50	5.0	4
21	2	100	1.5	4
22	1	200	1.5	4
23	2	50	1.5	5
24	3	300	5.0	5
25	1	100	5.0	4
26	3	50	3.0	5
27	3	100	3.0	3
28	3	200	5.0	3
29	1	300	3.0	4
30	3	50	5.0	3
31	2	100	5.0	5
32	1	100	3.0	3
33	2	200	1.5	5
34	2	50	5.0	4
35	2	100	3.0	5
36	2	300	5.0	5

Sequence 4

Target sequence No.	Number of targets	Range (meters)	Time up (seconds)	Delay (seconds)
1	3	300	5.0	5
2	3	50	5.0	3
3	1	100	3.0	3
4	1	50	1.5	3
5	1	200	1.5	4
6	3	50	3.0	3
7	3	300	1.5	3
8	3	200	1.5	3
9	1	200	5.0	3
10	1	100	1.5	5
11	3	200	3.0	5
12	2	200	1.5	5
13	1	300	3.0	4
14	1	200	3.0	3
15	1	300	5.0	4
16	2	100	1.5	4
17	3	100	1.5	4
18	3	200	5.0	3
19	3	300	3.0	5
20	3	50	1.5	3
21	2	100	5.0	5
22	2	100	3.0	5
23	2	200	3.0	5
24	2	50	5.0	4
25	2	200	5.0	4
26	2	300	5.0	5
27	2	300	1.5	4
28	1	50	5.0	4
29	1	100	5.0	4
30	3	100	5.0	3
31	1	300	1.5	4
32	2	50	1.5	5
33	2	300	3.0	3
34	1	50	3.0	4
35	3	100	3.0	3
36	2	50	3.0	5

Sequence 5

Target sequence No.	Number of targets	Range (meters)	Time up (seconds)	Delay (seconds)
1	3	100	5.0	3
2	3	300	1.5	3
3	2	100	3.0	5
4	2	300	3.0	3
5	3	200	1.5	3
6	2	300	1.5	4
7	1	100	5.0	4
8	2	100	5.0	5
9	1	50	1.5	3
10	1	100	1.5	5
11	2	200	3.0	5
12	1	100	3.0	3
13	1	200	1.5	4
14	3	50	1.5	3
15	2	200	5.0	4
16	3	100	3.0	3
17	3	200	3.0	5
18	2	300	5.0	5
19	3	100	1.5	4
20	1	300	5.0	4
21	3	200	5.0	3
22	2	50	1.5	5
23	1	300	1.5	4
24	3	300	3.0	5
25	1	50	3.0	4
26	2	100	1.5	5
27	1	300	3.0	4
28	3	50	3.0	5
29	2	50	3.0	5
30	3	300	5.0	5
31	1	200	3.0	3
32	2	50	5.0	4
33	1	50	5.0	4
34	1	200	5.0	3
35	2	200	1.5	5
36	3	50	5.0	3

Sequence 6

Target sequence No.	Number of targets	Range (meters)	Time up (seconds)	Delay (seconds)
1	1	200	3.0	3
2	3	50	5.0	3
3	1	100	1.5	5
4	2	50	3.0	5
5	1	200	5.0	3
6	2	100	1.5	4
7	3	300	1.5	3
8	3	200	1.5	3
9	1	50	1.5	3
10	1	200	1.5	4
11	1	100	5.0	4
12	3	100	5.0	3
13	2	300	5.0	5
14	2	300	1.5	4
15	2	100	5.0	5
16	3	200	3.0	5
17	2	100	3.0	5
18	3	50	3.0	5
19	3	100	1.5	4
20	3	200	5.0	3
21	1	50	5.0	4
22	1	300	1.5	4
23	2	50	1.5	5
24	2	200	1.5	5
25	1	100	3.0	3
26	3	50	1.5	3
27	2	200	3.0	5
28	1	300	3.0	4
29	1	50	3.0	4
30	2	200	5.0	4
31	2	50	5.0	4
32	3	300	5.0	5
33	1	300	5.0	4
34	3	300	3.0	5
35	3	100	3.0	3
36	2	300	3.0	3

APPENDIX I

PLAQUE

AWARDED FOR MARKSMANSHIP EXCELLENCE IN COMPETITION BETWEEN SOLDIERS OF THE 82ND AIRBORNE DIVISION AND THE 101ST AIRBORNE DIVISION (AIR ASSAULT) DURING EVALUATION OF SOLDIER PERFORMANCE USING ADVANCED M-16 RIFLE DESIGNS AND FIRING TECHNIQUES.

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